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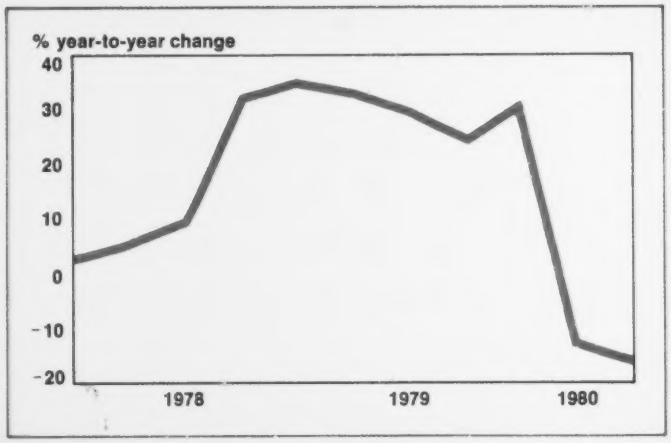
Chemical & Engineering NEWS

November 10, 1980

Researchers focus on brain tumors among chemical workers Page 33



CHEMICAL EARNINGS

Staying down after recession Page 10

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Chemical & Engineering NEWS

Cover: Interox America's hydrogen peroxide plant at Deer Park, Tex.

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News of the Week

- ***The Republican landslide*** *means new committee chairmen in the Senate, changes in some key House seats, outlook for decreased regulations and tax incentives.* **Page 6**
- ***Although businessmen look with favor*** *on the Reagan victory, most expect economic recovery to be gradual.* **Page 7**
- ***Formation of a gene-splitting company*** *in which Harvard University would be a shareholder is being delayed while questions of ethics are resolved.* **Page 7**
- ***Dow Chemical will expand its health care activities*** *by acquiring Richardson-Merrell's ethical pharmaceutical business for $260 million in Dow common stock.* **Page 8**
- ***ACS retains its tax-exempt status*** *as Internal Revenue Service decides that lower member subscription rates for journals are not violations of regulations.* **Page 8**

Business

- ***Third quarter may have been the bottom*** *for chemicals, as earnings fell an average of 15% and profit margins an average of 5% from third-quarter 1979.* **Page 10**
- ***Cabot is expanding its specialty alloy facilities*** *at Kokomo, Ind.; alloys find wide use in chemical process industries.* **Page 18**

International

- ***Good growth is ahead for engineering plastics*** *in Western Europe, with sales expected to reach 2.2 billion lb by 1985; key factor is product innovation.* **Page 19**

Government

- ***Political Action Committees*** *are becoming more influential in elections, contributing $32 million to federal candidates in this year's campaigns.* **Page 22**
- ***Safety of chemists in labs*** *is receiving more attention, with NRC report on handling hazardous chemicals, OSHA efforts to draft lab worker protection criteria.* **Page 24**
- ***Health problems at Love Canal*** *remain unresolved after yet another review.* **Page 25**

Science

- ***Evaluating evidence*** *that suggests elevated incidence of brain tumors in petrochemical workers is stretching science of epidemiology to its limits.* **Page 33**

Education

- ***Technical education faces troubled times;*** *teacher shortage, particularly in the field of engineering, reported as caused in part by low salaries.* **Page 37**

Technology

- ***Analytical chemists organize*** *to obtain professional recognition and improve their contributions to chemistry.* **Page 40**

Books

- ***New guide for university researchers*** *by Robert V. Smith offers helpful advice on managing research efficiently.* **Page 41**

Chemical profits may have hit bottom

Third quarter probably was the low point in recession for chemicals as earnings fell 15%, profit margins 5% from a year ago

William J. Storck
and William F. Fallwell
C&EN, New York

The third quarter was almost undoubtedly the low point in the current chemical recession as earnings and profit margins plunged from the heights reached a year ago. However, even though a turnaround may be under way, chemical companies are not yet out of the woods. Depressed earnings by year-to-year measures will last through the fourth quarter and probably into the first quarter of 1981.

In this year's third quarter, earnings of 36 of the 40 largest U.S. chemical companies (the other four have not reported) fell an average of 15.4% from the third quarter a year ago. Sales during the quarter increased an average of 6%. The combined effect was to lower profit margins for the 36 companies to an average of 5.0% from 6.3% in third-quarter 1979.

The poor performance during the quarter was not universal. Once again, the smaller, more specialized companies outperformed the big chemical firms. While the 20 largest chemical firms saw profits erode 20% from last year, 16 smaller companies on the list chalked up gains averaging 31% over 1979.

The same held true for sales. The 20 larger firms had a sales gain of 5% in the third quarter; sales at smaller companies increased an average of 17%.

Thus, although profit margins at the big companies fell to an average of 4.6% from 6.0% in last year's third quarter, profitability for the smaller companies rose a full percentage point to an average of 9.8% in this year's third quarter.

The same pattern held true in the first nine months of the year. Earnings for the 20 larger companies fell an average of 4% on a sales increase of 12%. Earnings for the 16 smaller firms rose an average of 49% on a sales increase of 17%. Nine-month profit margins for the big firms fell to 5.5% from 6.5% in the first three quarters of 1979. Profit margin for the more specialized group rose to 10.8% from 8.5% last year.

For the 36 companies as a whole, profits remained flat through the first three quarters whereas sales increased 13%. Return on sales dropped

Chemical industry leaders for third-quarter 1980 . . .

Sales			Earnings			Profitability		
Rank	$ Millions	Rank 1979		$ Millions[a]	Rank 1979		Earnings as % of sales	Rank 1979
1 Du Pont	$3167.7	1	Dow Chemical	$160.5	2	Texasgulf	24.1%	2
2 Dow Chemical	2521.3	2	Union Carbide	153.8	3	Freeport Minerals	20.6	1
3 Union Carbide	2383.7	3	Du Pont	98.1	1	Great Lakes Chemical	13.6	4
4 Monsanto	1538.7	4	Texasgulf	68.9	12	Lawter Chemicals	13.2	3
5 W. R. Grace	1487.0	5	Allied Chemical	66.2	18	Lubrizol	12.6	7
6 Allied Chemical	1323.0	6	W. R. Grace	64.3	6	Nalco Chemical	11.8	8
7 American Cyanamid	869.2	7	American Cyanamid	48.3	11	Petrolite	10.5	23
8 Celanese	785.0	8	PPG Industries	47.8	5	International Minerals	9.6	9
9 B. F. Goodrich	782.4	9	Diamond Shamrock	42.6	9	Mallinckrodt	7.7	10
10 Diamond Shamrock	773.2	11	Freeport Minerals	37.4	15	First Mississippi	6.6	24

. . . and for nine-months 1980

Sales			Earnings			Profitability		
Rank	$ Millions	Rank 1979		$ Millions	Rank 1979		Earnings as % of sales	Rank 1979
1 Du Pont	$10,149.9	1	Dow Chemical	$562.4	2	Texasgulf	30.3%	3
2 Dow Chemical	7,853.5	2	Union Carbide	523.6	3	Freeport Minerals	21.1	1
3 Union Carbide	7,320.2	3	Du Pont	519.1	1	Lawter Chemicals	15.0	2
4 Monsanto	4,909.8	4	Texasgulf	244.6	14	Great Lakes Chemical	14.8	5
5 W. R. Grace	4,392.5	5	Monsanto	217.0	4	Lubrizol	12.6	7
6 Allied Chemical	4,071.0	6	W. R. Grace	212.3	6	Nalco Chemical	11.5	8
7 American Cyanamid	2,536.2	8	Allied Chemical	207.5	11	Petrolite	10.0	12
8 Celanese	2,435.0	7	Diamond Shamrock	155.3	7	International Minerals	8.9	11
9 B. F. Goodrich	2,299.8	10	PPG Industries	142.2	5	First Mississippi	8.8	23
10 Diamond Shamrock	2,297.0	12	American Cyanamid	119.2	7	Mallinckrodt	8.0	13

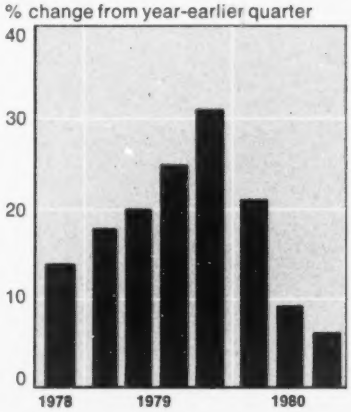
a After taxes. Note: For 40 chemical companies listed on page 12.

Chemical Industry Third-Quarter Results

- Sales growth slowed to 6%
- While earnings fell 16%
- Profit margins dropped
- Production was off 8.4%
- Price hikes slowed to 15.8%

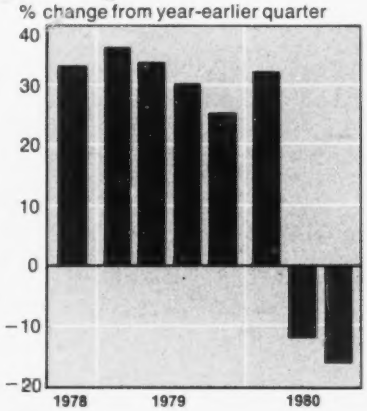
Sales

% change from year-earlier quarter



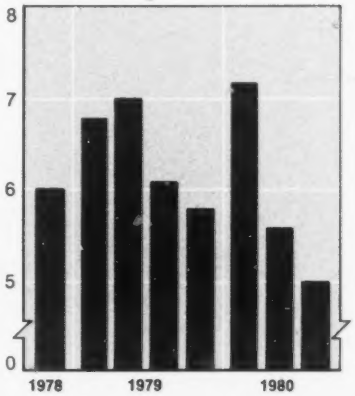
Earnings

% change from year-earlier quarter



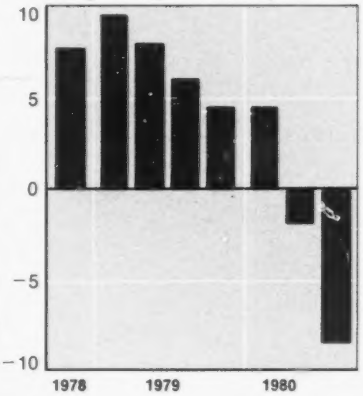
Profit margins

After-tax earnings as % of sales



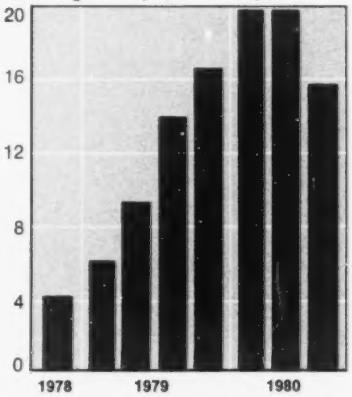
Production

% change from year-earlier quarter



Prices

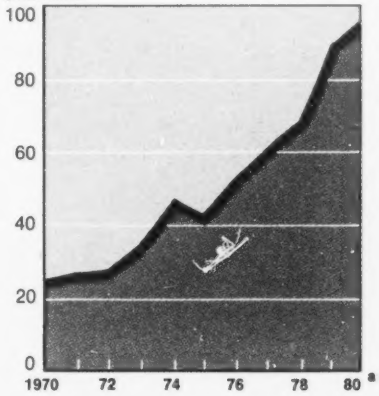
% change from year-earlier quarter



1980 sales likely will rise about 10% to top $97 billion; earnings will slip to $5.5 billion; profit margins will decrease to 5.6%

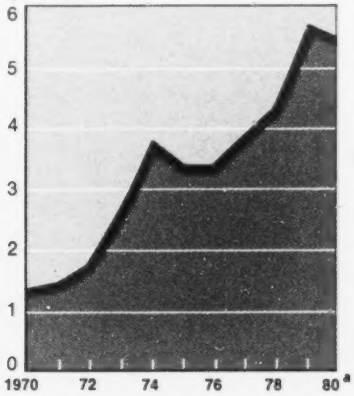
Annual sales

$ Billions



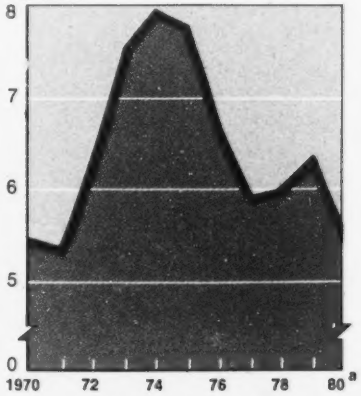
Annual earnings

$ Billions



Annual profit margins

Per cent



a C&EN estimates. **Note:** All sales, earnings, and profit margin data are based on the combined performance of the 40 largest chemical makers listed on page 12.

Third-quarter earnings fall 15% at chemical companies; profit margins off to 5.0%

	THIRD-QUARTER 1980						NINE-MONTHS 1980			
	Sales	Earnings	Change from 1979		Profit margin[a]		Sales	Earnings	Change from 1979	
	($ millions)		Sales	Earnings	1980	1979	($ millions)		Sales	Earnings
Du Pont[e]	$ 3,167.7	$ 98.1	1%	−58%	3.1%	7.5%	$10,149.9	$ 519.1	8%	27%
Dow Chemical	2,521.3	160.5	4	−19	6.4	8.2	7,853.5	562.4	15	−5
Union Carbide[f]	2,383.7	153.8	3	−14	6.5	7.7	7,320.2	523.6	8	3
Monsanto	1,538.7	29.6	3	−70	1.9	6.6	4,909.8	217.0	6	−32
W. R. Grace[g]	1,487.0	64.3	15	42	4.3	3.5	4,392.5	212.3	15	30
Allied Chemical[h]	1,323.0	66.2	6	245	5.0	1.5	4,071.0	207.5	34	92
American Cyanamid[i]	869.2	48.3	11	35	5.6	4.6	2,536.2	119.2	9	0
Celanese	785.0	21.0	1	−43	2.7	4.8	2,435.0	82.0	4	−28
B. F. Goodrich	782.4	8.7	5	−48	1.1	2.3	2,299.8	39.0	−4	−42
Diamond Shamrock[j]	773.2	42.6	28	15	5.5	6.1	2,297.0	155.3	36	30
PPG Industries	765.3	47.8	−2	−15	6.2	7.2	2,320.0	142.2	1	−13
Hercules[k]	582.0	27.9	−4	−33	4.8	6.9	1,852.0	88.5	6	30
Williams Cos.	519.8	28.2	18	137	5.4	2.7	1,573.7	115.6	13	151
International Minerals[l]	462.8	44.3	20	30	9.6	8.8	1,421.8	127.2	19	−30
Ethyl Corp[m]	429.9	19.2	−3	−32	4.5	6.3	1,309.0	64.5	7	−15
Olin[n]	429.1	12.1	0	2	2.8	2.8	1,387.8	61.4	4	8
Rohm & Haas[o]	403.9	22.6	3	−14	5.6	6.7	1,306.7	76.7	9	−1
Air Products	369.3	23.3	6	−11	6.3	7.5	1,104.2	84.4	16	12
Stauffer Chemical	329.8	4.5	6	−65	1.4	4.1	1,269.8	94.1	10	−6
Pennwalt	292.1	9.0	10	−22	3.1	4.3	887.3	32.2	12	−15
Texasgulf	285.7	68.9	49	96	24.1	18.3	806.3	244.6	42	164
Akzona	237.1	−3.9	−1	p	p	1.8	774.8	2.0	5	−90
Lubrizol	224.7	28.3	17	7	12.6	13.7	691.0	86.8	27	30
Reichhold Chemicals	214.0	4.7	−3	275	2.2	0.6	663.5	9.1	2	−6
Freeport Minerals[q]	181.5	37.4	40	35	20.6	21.5	485.5	102.6	36	40
Thiokol[r]	170.6	6.6	27	−25	3.9	6.6	478.7	23.9	15	−2
Nalco Chemical	156.5	18.4	7	16	11.8	10.8	454.1	52.2	8	12
International Flavors[s]	—	—	—	—	—	14.9	—	—	—	—
Mallinckrodt	107.4	8.3	12	11	7.7	7.8	328.8	26.4	12	14
Liquid Air[s]	—	—	—	—	—	6.8	—	—	—	—
Petrolite	65.8	6.9	46	165	10.5	5.8	189.9	18.9	40	72
Crompton & Knowles	58.1	1.5	4	0	2.6	2.6	181.0	6.0	1	30
First Mississippi	57.6	3.8	31	65	6.6	5.2	194.8	17.1	29	84
Beker Industries[s]	—	—	—	—	—	6.2	—	—	—	—
Loctite[s]	—	—	—	—	—	15.4	—	—	—	—
Essex Chemical[t]	42.1	1.1	24	−33	2.5	4.6	113.0	3.1	19	−27
Stepan Chemical[u]	39.3	0.4	4	−64	1.0	2.8	116.4	2.4	7	−47
Virginia Chemicals	34.0	0.2	6	−74	0.6	2.3	112.0	1.7	13	−61
Great Lakes Chemical	31.6	4.3	2	−11	13.6	15.9	92.1	13.6	1.8	0
Lawter Chemicals	19.7	2.6	20	−4	13.2	16.5	59.4	8.9	19	7
Total 20 largest companies	**$20,215.2**	**$ 932.0**	**5%**	**−20%**	**4.6%**	**6.0%**	**$62,697.2**	**$3524.2**	**12%**	**−4%**
Total 16 other companies	**$ 1,925.7**	**$ 189.5**	**17%**	**31%**	**9.8%**	**8.8%**	**$ 5,741.3**	**$ 619.3**	**17%**	**49%**
GRAND TOTAL	**$22,140.9**	**$1121.5**	**6%**	**−15%**	**5.0%**	**6.3%**	**$68,438.5**	**$4143.5**	**13%**	**0%**

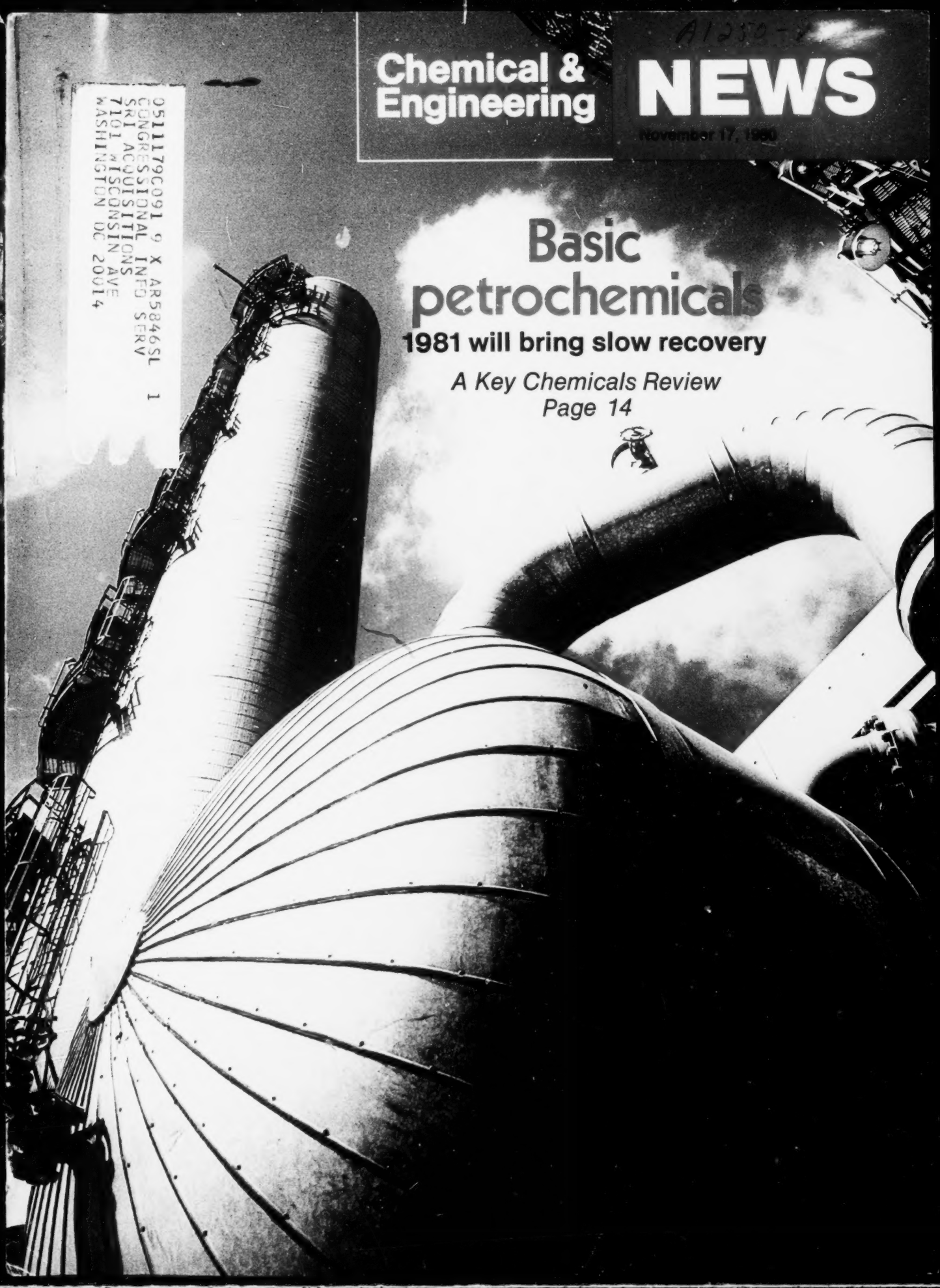
a After-tax income as percentage of sales. b For 12 months ending third-quarter 1980. c Fully diluted before nonrecurring items and extraordinary charges for continuing operations. d As of Oct. 31. e Third-quarter 1980 excludes nonrecurring charge of $9 million. Third-quarter 1979 exludes nonrecurring gain of $17.4 million. f Excludes $28.7 million charge in second-quarter 1979 and $86.2 million charge in nine-months 1979 for change in accounting methods; 12-months earnings per share and price/earnings ratio are approximate. g Excludes $3.6 million nonrecurring gain in third-quarter 1980, $14.8 million gain in third-quarter 1979, $7.2 million gain in nine-months 1980, and $4.3 million change in nine-months 1979 for gains and losses on divestitures. h Eliminates $142.9 million charge in third-quarter 1979. i Excludes $8.1 million charge in third-quarter 1980 and $3.4 million credit in third-quarter 1979. j Includes extraordinary

to an average 6.0% from 6.7% through the first nine months of 1979.

Chemical company executives are convinced, however, that a turnaround is under way. Harry W. Buchanan, chairman and president of Virginia Chemicals, says, "It appears that the segment of the domestic chemical industry in which Virginia Chemicals participates reached its low point early in the third quarter as all of our domestic businesses are showing improved operating results compared to those reported in the second quarter."

G. J. Williams, financial vice president of Dow Chemical, says, "The third quarter saw a definite turnaround in business in the U.S. in virtually all parts of the economy. The recovery began in August and has been sharper than we had anticipated."

At Monsanto, where physical product volume was off about 6% in the third quarter, John W. Hanley, chairman and chief executive officer, comments that the low point in demand in the U.S. was reached in July and August. "Since then, incoming



NINE-MONTHS 1980 Profit margin[a] 1980	NINE-MONTHS 1980 Profit margin[a] 1979	12-MONTH RUNNING DATA[b] Change from 1979 Sales	12-MONTH RUNNING DATA[b] Change from 1979 Earnings	12-MONTH RUNNING DATA[b] Profit margin[a] 1980	12-MONTH RUNNING DATA[b] Profit margin[a] 1979	Earnings per share[c] 3rd qtr	Earnings per share[c] Recent 12 months	STOCK MARKET DATA[d] Stock price	STOCK MARKET DATA[d] Price/earnings ratio	STOCK MARKET DATA[d] Dividend yield, % of price
5.1%	7.6%	10%	−25%	5.4%	8.0%	$0.64	$ 4.90	$39 3/4	8	5.0%
7.2	8.7	19	4	7.3	8.4	1.09	4.10	32 1/2	8	4.9
7.2	7.5	10	2	6.7	7.2	2.30	10.50	45 1/4	4	7.1
4.4	6.9	8	−47	3.6	7.2	0.81	6.44	56 3/8	9	6.4
4.8	4.3	17	42	4.8	3.9	1.43	5.61	49 5/8	9	4.6
5.1	3.6	41	86	5.1	3.9	1.80	8.08	55 1/4	7	4.0
4.7	5.1	11	1	4.9	5.3	1.01	3.43	27 7/8	8	5.7
3.4	4.9	8	−27	3.4	4.9	1.41	8.67	51 3/4	6	7.0
1.7	3.1	6	−44	1.6	3.0	0.48	2.81	23	8	6.8
6.8	7.1	37	29	7.2	7.7	0.75	3.94	32	8	5.3
6.1	7.2	3	−8	6.3	7.1	1.44	6.01	36 1/4	6	6.0
4.8	6.8	9	−22	4.7	6.5	0.64	3.38	20 3/4	6	5.8
7.3	3.3	18	191	6.8	2.8	1.02	5.07	39 5/8	8	2.8
8.9	8.2	21	31	8.8	8.1	1.63	7.21	49	7	4.7
4.9	6.2	8	−10	5.0	6.0	0.94	4.21	30 1/2	7	4.9
4.4	4.2	5	9	4.2	4.0	0.56	3.25	18 3/8	6	6.0
5.9	6.4	12	5	5.6	6.0	1.75	7.35	46 3/4	6	5.0
7.6	7.9	16	18	8.1	7.9	0.82	3.94	49 1/2	13	1.6
7.4	8.6	11	−3	7.9	9.0	0.10	2.95	18 3/4	6	6.4
3.6	4.8	14	−9	3.8	4.7	0.87	4.33	27 3/4	6	7.9
30.3	16.3	39	128	23.9	14.6	1.81	6.54	56 5/8	9	2.8
0.3	2.6	9	−31	1.6	2.5	(0.32)	0.80	11	14	7.3
12.6	12.3	27	30	12.4	12.2	1.46	5.71	69 1/2	12	2.6
1.4	1.5	5	−7	1.3	1.5	0.57	1.25	12 1/2	10	3.8
21.1	20.5	40	52	20.9	19.3	1.18	4.49	57 1/8	13	1.8
5.0	5.8	12	−7	5.5	6.7	0.57	2.97	31 1/4	11	3.2
11.5	11.1	11	11	11.2	11.2	0.92	3.44	46 1/4	13	3.5
—	15.5	—	—	—	15.2	—	—	20 1/2	11	4.5
8.0	7.9	12	15	8.2	8.0	0.85	3.63	42 5/8	12	3.3
—	6.8	—	—	—	6.1	—	—	29 1/2	11	4.7
10.0	8.1	34	53	9.8	8.5	1.16	3.98	89	22	1.4
3.3	2.6	2	17	3.3	2.9	0.63	3.68	21	6	5.7
8.8	6.2	32	160	8.8	4.5	0.44	2.62	56 3/4	22	0.9
—	p	—	—	—	0.8	—	—	19 3/4	7	—
—	14.5	—	—	—	14.7	—	—	29	15	1.9
2.8	4.5	18	−32	2.6	4.5	0.44	1.62	12 3/4	8	6.3
2.0	4.1	8	−56	1.8	4.3	0.20	1.45	19 1/8	13	4.8
1.5	4.4	15	−69	1.1	4.1	0.07	0.62	23 1/2	38	3.0
14.8	15.0	10	6	14.8	15.3	0.60	2.47	41 1/8	17	1.0
15.0	16.6	19	8	15.1	16.6	0.23	1.01	12 3/8	12	6.9
5.5%	**6.5%**	**14%**	**−2%**	**5.6%**	**6.5%**					
10.8%	**8.5%**	**18%**	**43%**	**9.9%**	**8.2%**					
6.0%	**6.7%**	**14%**	**2%**	**6.0%**	**6.6%**					

item. **k** Excludes $10.7 million charge in third quarter and $27.6 million nonrecurring gain in third-quarter 1979. **l** Excludes $4.3 million charge in second-quarter 1980. **m** Ethyl had cumulative $500,000 nonrecurring gain in nine-months 1980. **n** Olin had nonrecurring charge of $1.1 million in third-quarter 1979. **o** Excludes $3.0 million nonrecurring gain in third-quarter 1979 and $7.3 million gain in nine-months 1979. **p** Deficit. **q** Excludes $500,000 gain in third-quarter 1980, $6.2 million gain in nine-months 1980, and $2 million gain in nine-months 1979. **r** Excludes nonrecurring gains of $100,000 in third-quarter 1980, $2.6 million in third-quarter 1979, $800,000 in nine-months 1980, and $5.6 million in nine-months 1979. **s** Not all data available at press time. **t** Excludes gains of $600,000 in third-quarter 1980 and $700,000 in nine-months 1980. **u** Excludes $1.7 million gain in third-quarter 1979.

orders have been improving. As a result, our plants are operating at higher levels of capacity utilization."

And at PPG Industries, chairman L. Stanton Williams remarks, "The economic downturn may have bottomed out. Following a steep decline in the second quarter, volume has stabilized in many of our markets, and some showed improvements as the quarter progressed. As a consequence, third-quarter earnings improved, although still lagging 1979 levels."

At many companies, third-quarter earnings were hurt by continued poor performance in plastics. For example, at Celanese, earnings from plastics and specialties fell more than 70% in the third quarter from the same period last year. Monsanto suffered a loss in pretax income of $20.2 million on plastics and resins in the third quarter this year after a $12.2 million pretax profit in the third quarter of 1979.

B. F. Goodrich chairman John D. Ong says that third-quarter sales remained soft for most of the compa-

Earnings begin to drop at some chemical-producing oil companies

	% chemical sales	THIRD-QUARTER 1980 Sales ($ millions)	Earnings	Change from 1979 Sales	Earnings	Profit margin[a] 1980	1979	NINE-MONTHS 1980 Sales ($ millions)	Earnings	Change from 1979 Sales
Exxon	7%	$26,745.0	$1355.0	23%	18%	5.1%	5.3%	$80,622.0	$4310.0	36%
Mobil[b]	3	15,629.0	721.0	26	20	4.6	4.9	46,304.0	2254.0	38
Texaco[b]	3	12,625.0	636.4	24	9	5.0	5.7	38,411.2	1739.9	42
Standard Oil of California	3	10,509.0	624.0	29	17	5.9	6.6	31,605.0	1786.0	43
Gulf Oil[b]	9	6,631.0	244.0	−2	−41	3.7	6.2	21,187.0	1003.0	15
Standard Oil (Ind.)	9	6,487.6	488.9	27	3	6.9	8.5	20,134.4	1513.1	42
Atlantic Richfield[b]	10	5,636.8	274.7	29	−14	4.9	7.3	16,765.4	1138.1	44
Shell Oil	14	5,135.0	353.0	36	20	6.9	7.8	14,828.0	1133.0	45
Conoco[b]	6	4,500.0	207.4	32	−3	4.6	6.3	13,500.0	785.6	45
Phillips Petroleum	20	3,220.0	283.4	29	47	8.8	7.7	9,840.0	782.6	47
Tenneco	13	3,068.0	162.0	10	24	5.3	4.7	9,585.0	526.0	21
Sun Co.	3	3,000.0	194.9	11	7	6.5	6.7	9,100.0	693.2	20
Occidental Petroleum	21	2,951.3	133.7	13	−28	4.5	7.1	9,296.5	572.7	39
Union Oil	11	2,630.1	122.0	23	15	4.6	4.9	7,757.1	469.8	34
Getty Oil	3	2,558.6	191.8	92	10	7.5	13.1	7,470.6	660.8	109
Standard Oil (Ohio)	5	2,542.7	433.4	21	18	17.0	17.5	8,042.0	1335.4	44
Ashland Oil[b]	13	2,148.5	62.7	13	19	2.9	2.8	6,269.5	157.8	21
Cities Service	8	1,635.4	92.6	2	8	5.7	5.4	5,621.7	369.7	26
Kerr-McGee	16	893.9	33.7	31	−21	3.8	6.3	2,528.5	130.4	31
El Paso	11	882.2	8.7	6	−77	1.0	4.6	2,835.1	49.6	30

a After-tax income as percentage of sales. b Excludes major nonrecurring earnings: Mobil—$459 million in first-quarter 1980; Texaco—$402 million in first-quarter 1980; Gulf Oil—$100 million in second-quarter 1980; Atlantic Richfield—$115 million in third-quarter 1980; Conoco—$32.6 million in third-quarter 1979; Ashland Oil—$27.4 million charge in third-quarter (calendar) 1980 and $345.1 million gain in second-quarter 1979.

ny's industrial products and that industry price discounting offset improving demand for polyvinyl chloride resins.

And at Hercules, polypropylene resin business was particularly hard hit by a combination of lower volume and the need to reduce prices under competitive pressure.

Generally, specialty chemicals performed well at chemical companies, except when they were selling into the depressed automobile, plastics, and construction markets.

One of the companies that was hit by the downturn in these industries was Thiokol. Chairman and president R. E. Davis says that the sharp drop in pretax earnings in specialty chemical operations was caused by a number of factors—reduced volume in the plastic additive and disc brake pads lines and decreased sales of all products used by construction and automotive markets are just two.

However, things were not so bleak at other chemical firms. Oil field chemicals seemed to be going very well. Ellis L. Brown, chairman and president of Petrolite, says that the company's earnings gain of 165% over last year was due primarily to strongly growing demand for Petrolite's oil field chemicals. Brown says that unit volume sales of Petrolite's oil field chemicals were up 10% in North American markets and up more than 35% abroad through the first nine months. He does not break out quarterly figures. Nalco Chemical says that the largest contribution to its 19% sales gain was from its oil field chemicals operations.

The one bright spot for chemical companies in the third quarter continued to be agricultural chemicals—both fertilizers and pesticides. For example, operating income in agricultural products, mainly herbicides, at Monsanto increased 29% in the third quarter to $81.4 million on a sales increase of 26%.

Fertilizers also have performed well in the third quarter for most companies, which see continued good performance. Joseph M. Williams, chairman of Williams Cos., says that superior performances in the fertilizer and energy sectors of its businesses produced a continuation of the very favorable first-half trend in the company's operating results.

International Minerals & Chemical forecasts a 15 to 20% increase in per share earnings for its fiscal year ending June 30, 1981. According to chairman R. A. Lenon, "A large part of the anticipated gains for the fiscal year ending next June 30 will come from strong demand for animal products and for phosphate and potash fertilizer materials. A high level of fertilizer exports seems certain and it appears, as of now, that U.S. farmers will be increasing their use."

Among the many important investors in agricultural chemicals outside the basic chemical company group, fertilizer also was generally better off this summer than last. For example, the chemical division of Occidental Petroleum credits higher fertilizer prices and volumes for much of its 33% after-tax earnings improvement in the third quarter over third-quarter 1979.

However, there are signs that not all pesticide operations had an easy time in the torrid summer drought in parts of the U.S. For example, FMC says that its agricultural chemical sales were slightly lower than a year ago, as poor cotton growing conditions and "reduced pest pressure" lowered demand for the highly touted synthetic pyrethroid products. As a result, its profit margins were lower than last year, and agricultural chemical earnings declined substantially more than did sales.

In other chemical product areas, the diversified chemical producers generally ran into a recessionary drag on earnings in the third quarter. The worst markets, as earlier in 1980, were automobile and housing.

For example, at Borden, chairman Eugene J. Sullivan notes that chemical division earnings were down "sharply" in the third quarter because of the recession in housing and autos. And at Occidental Petroleum's chemical division, the good gains in fertilizer were partially offset by lower

NINE-MONTHS 1980			STOCK MARKET DATA							
Change from 1979	Profit margin[a]		Earnings per share		Stock price			Price-earnings ratio	Annual indicated	Dividend yield, %
Earnings	1980	1979	3rd qtr	Recent 12 months	Oct. 31	Recent 12 months High	Low	Oct. 31	dividend	of price
47%	5.4%	5.0%	$3.13	$12.99	$76 1/8	$80 3/4	$52	6	$6.00	7.9%
53	4.9	4.4	3.39	13.52	74 1/2	89 1/2	46 3/8	6	4.00	5.4
42	4.5	4.5	2.37	8.42	38 1/2	41 5/8	27 1/8	5	2.60	6.8
42	5.7	5.7	3.64	13.50	84 3/8	93 1/2	52 7/8	6	3.60	4.3
5	5.2	5.2	1.25	7.02	39 3/4	54 1/2	31 3/4	6	2.50	6.3
33	7.5	8.0	1.53	6.40	73	75 1/2	46	11	2.20	3.0
38	6.8	7.1	1.11	5.41	60 1/8	66 3/4	42 1/4	11	1.90	3.2
43	7.6	7.8	1.14	4.75	45 1/2	51 1/2	34	10	1.60	3.5
33	5.8	6.4	1.92	9.36	58 5/8	65	41	6	2.20	3.8
34	8.0	8.7	1.86	7.10	52 1/8	61 1/8	37 5/8	7	1.80	3.5
29	5.5	5.1	1.25	5.87	42 1/2	48 1/4	31 1/4	7	2.60	6.1
45	7.6	6.3	1.54	7.26	46 1/2	57 1/2	33 1/4	6	1.80	3.9
53	6.2	5.6	1.54	9.00	31	33 7/8	19	3	2.00	6.5
35	6.1	6.0	0.71	3.60	47 5/8	52 1/2	27 5/8	13	1.00	2.1
57	8.9	11.8	2.33	10.25	89 1/2	99 1/4	63	9	1.80	2.0
75	16.6	13.2	1.77	7.31	67 3/8	72 7/8	42 1/4	9	1.80	2.7
21	2.5	2.5	1.99	6.95	37 1/8	42 3/4	25 3/4	5	2.20	5.9
53	6.6	5.4	1.11	5.73	44	48 3/8	29 3/8	8	1.60	3.6
9	5.2	6.2	1.30	6.59	84 5/8	92 3/8	52	13	1.80	2.1
−55	1.8	5.1	0.18	1.64	24 5/8	30 1/2	15 3/4	15	1.48	6.0

Petrochemical earnings at leading oil companies magnify the crunch

As they did in the previous recession in 1974–75, petrochemical earnings at leading U.S. oil companies joined the recession late but then really collapsed. This part of the chemical business, close to the big price swings of raw material oil and natural gas and not protected by premium product prices, tends to do an especially wild version of the ordinary business cycle. The highs are very high, and the lows are the opposite. In between is frequently a year or two of doldrums.

The third quarter of 1980 was one of those lows. For seven major petrochemical producers tabulated below, combined worldwide after-tax chemical earnings fell 6% from third-quarter 1979. For the year to date, 1980 earnings are now down 17% from the first nine months of 1979, after holding to the plus side through the first half from first-half 1979.

Although practically everything in petrochemicals had a bad quarter, the damage was relatively greater in the U.S. than outside. The prime reason was a plunge in basic business, the pounds of product sold.

For example, Gulf Oil reports that its worldwide physical product sales fell 17% in the third quarter from a year ago. However, its U.S. volume in petrochemicals and plastics dropped 29%. As a result, U.S. chemical earnings fell into the red, losing $37 million in the latest quarter after making $67 million in third-quarter 1979. Meanwhile, Gulf's foreign chemical earnings, mostly in Canada, rose to $25 million in third-quarter 1980 from $15 million in third-quarter 1979.

At the largest petrochemical producer, Exxon, worldwide chemical product revenue (including intracompany transfers) still rose 8% in dollar volume in the third quarter from a year earlier and rose 29% in the first nine months. However, chairman C. C. Garvin Jr. notes that in the first three quarters, "U.S. chemical earnings declined 27% due to a 4% drop in [physical] sales volume and reduced [profit] margins due to a general recession-related market softness. Abroad, earnings were up 29% from improved margins, particularly during the early part of the year; sales volume abroad was down 6%."

The geographic difference shows up in Exxon's third-quarter chemical earnings; they were down 65% in the U.S. from third-quarter 1979 and 33% abroad.

Petrochemical profit margins, robust a year ago, have fallen to at least the 5% level shared by the rest of the chemical industry, and probably have fallen lower. For example, Shell Oil data show its segment net income (after taxes but before corporate overhead) at 4.8% of sales in chemicals in the third quarter after a high 9.9% a year ago. A similar comparison at Standard Oil (Ind.) gives a margin of 1.8% in third-quarter 1980 after 9.0% in third-quarter 1979.

AFTER-TAX EARNINGS

$ Millions	Third quarter 1980	Third quarter 1979	% change	Nine months 1980	Nine months 1979	% change
Conoco	$ 5.7	$ 20.7	−72%	$ 49.4	$ 58.0	−15%
Exxon	58.0	103.0	−44	327.0	320.0	2
Gulf Oil	−12.0	82.0	deficit	115.0	196.0	−41
Mobil	21.0	36.0	−41	83.0	95.0	−12
Shell Oil	33.0	66.0	−50	110.0	140.0	−21
Standard Oil (Ind.)	10.5	56.7	−81	115.8	147.3	−21
Texaco	8.4	26.2	−68	47.6	67.0	−29
TOTAL	$124.6	$390.6	−68%	$847.8	$1023.3	−17%

Earnings tumble at many diversified chemical producers

	% chemical sales	THIRD-QUARTER 1980 Sales ($ millions)	Earnings ($ millions)	Change from 1979 Sales	Change from 1979 Earnings	Profit margin[a] 1980	Profit margin[a] 1979	NINE-MONTHS 1980 Sales[a] ($ millions)	Earnings ($ millions)	Change from 1979 Sales
Engelhard Minerals	1%	$6210.4	$127.0	47%	21%	2.0%	2.5%	$18,829.4	$ 407.5	73%
General Electric	2	5962.6	358.4	6	5	6.0	6.7	18,040.7	1102.5	10
Procter & Gamble[b]	4	2907.5	194.4	9	5	6.7	7.0	8,394.0	504.4	13
U.S. Steel[c]	9	2761.1	77.0	−14	−13	2.8	2.7	9,076.5	314.5	−8
Dart & Kraft[b]	8	2387.4	84.2	6	−7	3.5	4.0	6,961.4	285.9	6
Eastman Kodak	19	2358.9	358.8	18	26	15.2	14.3	6,626.6	847.2	22
Goodyear Tire & Rubber	12	2135.7	51.5	6	61	2.4	1.6	6,230.5	145.3	1
3M	15	1562.0	179.0	10	3	11.5	12.3	4,574.0	503.7	12
Georgia-Pacific	10	1278.0	74.0	−8	−13	5.8	6.1	3,700.0	179.0	−4
Aluminum Co. of America	9	1261.0	74.7	8	−30	5.9	9.2	3,854.1	367.1	8
Firestone Tire & Rubber[b]	13	1152.0	−32.1	−12	d	d	d	3,615.3	−48.9	−6
Borden[b]	34	1145.5	37.2	5	−4	3.3	3.6	3,491.9	107.5	10
FMC	34	829.0	21.4	3	−17	2.6	3.6	2,578.1	101.5	6
Esmark	25	782.6	13.3	16	25	1.7	1.6	2,130.4	38.9	13
Kaiser Aluminum	14	761.3	48.9	8	−7	6.4	7.5	2,450.4	204.6	11
Pfizer	14	759.4	67.3	11	4	8.9	9.5	2,204.0	190.3	10
Northwest Industries	5	708.7	38.5	7	−14	5.4	6.7	2,050.5	100.6	9
Martin Marietta	12	697.4	51.3	31	−5	7.4	10.2	1,908.3	144.6	28
Merck[b]	16	693.5	113.7	18	19	16.4	16.2	2,023.3	334.6	15
North American Philips	14	648.2	14.4	11	−14	2.2	2.9	1,897.0	46.6	9
Borg-Warner	22	619.7	20.9	−6	−41	3.4	5.4	1,969.4	88.3	−2
Eli Lilly	21	601.6	79.3	15	11	13.2	13.7	1,919.0	274.0	13
Koppers	30	555.0	23.3	7	−28	4.2	6.3	1,420.6	43.4	8
Uniroyal[b]	21	530.0	−3.3	−6	d	d	d	1,703.3	−18.0	−15
General Tire & Rubber	21	527.2	14.6	−5	−30	2.8	3.8	1,570.5	10.2	−6
NL Industries[b]	30	517.9	42.4	14	30	8.2	7.2	1,533.8	118.7	15
SCM	13	474.5	17.7	1	21	3.7	3.1	1,422.8	45.8	3
National Distillers[b]	37	472.0	19.0	−4	−19	4.0	4.8	1,543.2	91.7	−1
Upjohn	20	432.8	39.2	18	14	9.1	9.4	1,309.7	135.5	17
Emhart[b]	19	409.9	11.1	4	10	2.7	2.5	1,316.4	47.6	17
Sherwin-Williams[b]	7	348.8	11.4	7	47	3.3	2.4	967.3	23.7	6
GAF[c]	24	316.3	4.0	−3	−61	1.3	3.2	918.5	12.7	3
Vulcan Minerals[c]	33	195.7	19.9	0	−10	10.2	11.3	554.5	49.3	2
Ferro	15	174.6	9.1	14	13	5.2	5.2	515.1	20.9	18
Big Three Industries	34	170.5	22.0	30	37	12.9	12.2	477.6	62.7	28

a After-tax income as percentage of sales. b Excludes major nonrecurring earnings: Proctor & Gamble—$75 million charge in third-quarter (calendar) 1980; Dart & Kraft—$22.2 million in third-quarter 1979; Firestone—$49 million charge in second-quarter 1980; Borden—$6.5 million in third-quarter 1980; Merck—$10.4 million in third-quarter 1979; Uniroyal—$4.0 million

earnings in plastics and metal-finishing chemical specialties owing to depressed conditions in automotive, appliance, and housing markets.

Since these markets are major outlets for polymers and hence for many organic chemicals, petrochemicals were under pressure in the third quarter. Aside from the major damage at oil companies' chemical earnings, earnings for many downstream operations dropped. For example, National Distiller's petrochemical operations, the largest contributor to corporate earnings, sustained slightly lower earnings this third quarter compared to last. Chairman Drummond C. Bell remarks that polyethylene products were adversely affected by higher raw material and utility costs and by a small dip in volume. However, Distillers' industrial alcohol and natural gas liquids products benefited from firm selling prices. Another petrochemical problem at Distillers was its joint synthesis gas-based complex with Du Pont outside Houston, in startup this year. Bell says that Distillers' joint venture facility did not operate during most of the third quarter.

However, as in the large basic chemical companies, there are signs that the worst is past. For example, Georgia-Pacific, deep in the building market as well as in chemicals, senses a change. Chairman Robert E. Flowerree says, "Demand for polyvinyl chloride resin is still off, but improvement in building products markets helped product lines closely related to that industry, and our other chemical lines are also doing well."

A few nonorganics actually had a good quarter this summer, in contrast to most of the chemical product spectrum. Tops was probably caustic soda, which stayed in tight supply with rising prices because of weakness in coproduct chlorine. For example, Vulcan Materials says that strong caustic prices and a newly acquired chlor-alkali plant pushed up its chemicals sales 14% and earnings 16% from a year ago.

Another alkali, soda ash, also did well in the third quarter. This is FMC's largest-volume chemical product, and the company says soda ash sales and earnings were higher in the third quarter than a year ago.

However, most chemical operations

NINE-MONTHS 1980			STOCK MARKET DATA							
Change from 1979	Profit margin[a]		Earnings per share		Stock price			Price-earnings ratio	Annual indicated	Dividend yield, %
				Recent		Recent 12 months				
Earnings	1980	1979	Oct. 31	12 months	Oct. 31	High	Low	Oct. 31	dividend	of price
92%	2.2%	1.9%	$1.85	$7.92	$54	$61 7/8	$20 1/8	7	$1.16	2.1%
7	6.1	6.3	1.58	6.53	54 1/8	58 1/8	44	8	3.00	5.5
8	6.0	6.3	2.35	7.88	67 5/8	82 3/4	62 3/4	9	3.80	5.6
−16	3.5	3.8	0.88	−3.29	21 7/8	25	16 1/4	d	1.60	7.3
5	4.1	4.1	1.54	6.46	41 1/2	45 1/8	40 3/4	6	3.20[e]	7.7[e]
20	12.8	13.0	2.22	7.07	68 1/8	72 1/2	42 7/8	10	3.00	4.4
5	2.3	2.3	0.71	2.10	17 1/8	17 3/8	10 3/4	8	1.30	7.6
3	11.0	12.0	1.52	5.72	55 7/8	62 7/8	46 1/4	10	2.80	5.0
−30	4.8	6.7	0.70	2.33	25 3/4	37 7/8	21 1/2	11	1.20	4.7
−1	9.5	10.4	2.00	13.47	66 7/8	76 3/8	48 1/2	5	3.20	4.8
d	d	2.0	−0.56	−0.42	9 3/8	9 3/4	6 1/8	d	0	0
3	3.1	3.3	1.13	4.19	26 3/8	27 7/8	19 5/8	5	1.90	7.2
−9	3.9	4.6	0.60	3.91	25	31 1/8	21 5/8	6	1.60	6.4
2	1.8	2.0	0.56	2.88[e]	52 3/8	62	24 7/8	18[e]	1.84	3.5
21	8.4	7.6	1.10	6.09	24 3/8	30 1/4	15 3/8	4	1.40	5.7
6	8.6	9.0	0.92	3.40	44 1/4	49 1/8	32	13	1.44	3.3
−19	4.9	6.6	1.25	4.83	36	39 1/4	24 3/4	7	2.28	6.3
3	7.6	9.4	2.06	7.31	59	65 3/4	35 1/4	8	2.32	3.9
15	16.5	16.5	1.52	5.68	74 3/4	82 3/8	58 1/4	13	2.30	3.1
−16	2.5	3.2	1.06	5.37	35 3/4	37	23 1/2	7	1.70	4.8
−22	4.5	5.7	0.95	6.05	42	44 1/2	29 3/4	7	2.48	5.9
5	14.3	15.5	1.04	4.67	51 3/8	63 7/8	45 3/4	11	2.30	4.5
−29	3.1	4.7	0.85	2.43	28 1/2	35 1/4	19	12	1.40	4.9
d	d	d	−0.12	−1.59	6	6 3/8	3 1/8	d	0	0
−85	0.7	4.0	0.61	1.09	19 3/8	23 7/8	12 1/4	18	1.50	7.7
43	7.7	6.2	1.25	4.38	62 1/4	64 7/8	26	14	1.40	2.2
14	3.2	2.9	1.70	5.86	25 7/8	32 1/4	16 5/8	4	1.80	7.0
10	5.9	5.4	0.52	3.67	31 1/2	33 3/8	22	9	2.00	6.3
15	10.4	10.6	1.31	5.60	60 3/4	67	40 3/8	11	2.00	3.3
−1	3.6	4.3	0.88	4.27	31	35 5/8	23 1/4	7	2.40	7.7
41	2.5	1.8	1.89	4.47	37 3/4	40 3/8	23 1/8	8	1.20	3.2
−38	1.4	2.3	0.23	1.23	11 3/8	14 1/2	7 3/4	9	0.80	7.0
9	8.9	8.3	1.72	5.86	40 3/8	47 1/2	30 1/2	7	2.00	4.7
−6	4.1	5.1	1.18	3.85	20 3/4	24 1/4	17	5	1.20	5.8
37	13.1	12.2	1.04	3.82	65 3/4	72 1/4	37	17	1.00	1.5

in third-quarter 1980; NL Industries—$26.3 million in first-half 1979; National Distillers—$19.2 million charge in third-quarter 1980 and $17 million gain in second-quarter 1979; Emhart—$3.9 million in second-quarter 1980; Sherwin-Williams—$1.6 million charge in third-quarter 1980. c 1980 earnings include major nonrecurring items. d Deficit. e Estimate.

hidden in diversified nonchemical companies met the same profits trouble in the third quarter that dogged the main chemical industry. Although most oil and natural gas companies' earnings in the third quarter still rose at least modestly from a year earlier, six of this robust group began to see an earnings decline—Gulf Oil, Atlantic Richfield, Conoco, Occidental Petroleum, Kerr-McGee, and El Paso. For the rest, earnings increases were generally much less than earlier in 1980. All told, profit margins were down for 16 of the 20 companies. Sales still rose at all companies except Gulf Oil.

Outside the petroleum group, the going was rougher. Of the 35 diversified companies covered in C&EN's earnings survey of important chemical producers, 18 suffered earnings declines in the third quarter from third-quarter 1979, and an additional four had gains of 5% or less. Profit margins fell for 22 companies.

Sales of the diversified companies show much of the story behind the profits trouble. The pace dropped in the third quarter from nine months averages at 20 of the 35 companies. At eight companies, sales actually fell from third-quarter sales in 1979—U.S. Steel, Georgia-Pacific, Firestone, Borg-Warner, Uniroyal, General Tire, National Distillers, and GAF.

Signals of recovery began surfacing late in the period, including higher orders, price firmness, and a lower ratio of inventories to sales.

Even so, it will take two to three more quarters for this improvement to work its way to the earnings line in overall industry reports. By mid-1981, there once again may be more gains than declines in profit comparisons with a year ago.

For 1980, it is obvious now that chemical profits for the year will decline slightly from 1979 on a much reduced pace in dollar sales. For basic chemical companies, the annual figures will show something like a 1 to 5% earnings drop on a 10% sales gain from 1979.

That's nothing like the 29% earnings jump in 1979 from 1978 on an outsized 22% sales increase. But it's also not the worst performance for a bad recession year. By contrast, in the previous recession of 1975, chemical earnings decreased 15% on a sales increase of only 2%. □

Engineering plastics: European outlook bright

Key factor behind growth in demand for these specialty thermoplastics, expected to reach 2.2 billion lb by 1985, is product innovation

"Engineering thermoplastics are entering a new phase," notes John M. S. Brown, resin product manager at General Electric Plastics in Bergen op Zoom, the Netherlands. "The small, easy applications are over. The bulk of future growth will come from large functional parts requiring a more sophisticated level of technical support to the end user, and very often a modification of the basic polymer."

Adds Kenneth C. Sleep, development manager at Imperial Chemical Industries' plastics division in Welwyn Garden City near London, "During the next 10 years, I am confident that innovation will continue to be a key factor contributing to the strength and growth of the thermoplastics business. Industry has consistently recognized that product innovation is a sustaining strength."

Brown and Sleep made their remarks recently before the 260 attendees at the European Chemical Marketing Research Association conference in Estoril, Portugal. Its theme was "innovation—still the basis of growth," so it was hardly surprising that considerable interest was given to the more esoteric specialty resins.

C&EN staff photo

Brown: entering a new phase

Specialty engineering thermoplastics are high-performance materials that can be molded or extruded. They excel in such physical properties as tensile strength and stiffness, creep resistance and impact resistance, in many cases retaining these properties at temperatures exceeding 200° C.

Since they became available in commercial quantities some 20 years ago, demand has grown more than 15% annually. Brown indicates, however, that in the absence of some basic or dramatic change in their property profile or price, growth likely will start to slow down.

Moreover, he adds, the number of products competing in the market has more than doubled in the past six years. "The polymers that were available in 1974 have greatly expanded their property profiles. This has been done through addition of additives and fillers to enable [a polymer] to compete in an ever-expanding application base.

"The other important factor is that the majority of the new products are alloys. For example, we see acrylonitrile-butadiene-styrene alloyed with polyvinyl chloride, polycarbonate, or polysulfone to cover a much wider property spectrum."

Over the past five years or so, there has been increasing use of the materials in developing countries primarily as "a third country sourcing operation," as Brown puts it. For example, polymer made in Japan is exported to Taiwan where parts are molded and assembled. These are re-exported to Japan and elsewhere.

"Very little local demand exists at present [in developing countries]," Brown says. "However, I believe that as molding and design expertise increases, their share of engineering plastics consumption will increase to 10 or 15% of the worldwide market in the next 10 years.

"We are seeing a quiet revolution throughout the engineering plastics arena," Brown comments. "What emerges now is the need for expanded geographical participation and the need to sharpen the innovation cycle.

Engineering thermoplastics sales will near 2.2 billion lb in 1985

Millions of lb	1985	1979	Annual growth
Acrylics	389.7	308.0	4%
Polyamides	546.1	385.0	6
Polyacetals	156.3	116.6	5
Polycarbonates	226.9	143.0	8
Polyphenylene oxides	148.1	79.2	11
Polyesters[a]	674.6	204.6	22
Aromatic polymers[b]	36.6	17.6	13
TOTAL	2178.3	1254.0	10%

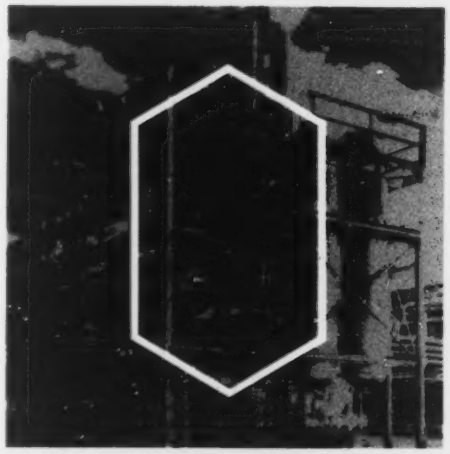
a Polyethylene terephthalate and polybutylene terephthalate. b Includes polysulfones, polyaryiethersulfones, polyaryletherketones, polyphenylene sulfides, and polyamideimides. **Source:** Imperial Chemical Industries

"The innovation cycle can only be brought into sharper focus through stronger links among the end users, the processors, and the raw material producers. These three partners must work closely to establish clear market needs, share the involved risk, and make the development process as short as possible."

Echoing these sentiments, ICI's Sleep is "confident that innovation will continue to be a key factor contributing to the strength and growth of the thermoplastics business." He foresees an average annual growth rate of 4.5% in Western Europe up to 1985, more than double the 2% per year expected growth of industrial output generally.

"In the specialty thermoplastics category, continued innovation and substitution is expected to lead to an average growth rate [in Western Europe] of 10%, two-and-a-half times higher than that for the bulk thermoplastics," Sleep predicts. He also makes the point that while the engineering plastics category "accounts for less than 5% of the bulk plastics tonnage, it represents 15% in terms of sales value." Last year, 27.3 billion lb of bulk thermoplastics were sold throughout Western Europe, according to Sleep.

Engineering thermoplastics comprise acrylics, polyamides, polyacetals, polycarbonates, polyphenylene oxides, polyethylene terephthalates (PET) and polybutylene terephtha-



COSDEN IS AROMATICS

Cosden could be your source of petrochemicals. A reason is the plentiful, assured supply of aromatic feedstocks from two refineries of American Petrofina, Incorporated, Cosden's parent company.

Cosden has an established position in such aromatics as benzene and toluene. In addition to being useful for specialty solvents, additives, and like uses, they provide the basis for other petrochemicals such as cyclohexane, ethylbenzene, styrene monomer, ethyltoluene, vinyltoluene; and the polystyrene, SAN and ABS polymers. What's more, Cosden has access to other valuable non-aromatic petrochemicals — propylene and butylenes — from American Petrofina's two refineries. They are useful building blocks for many other petrochemicals and polymers.

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lates (PBT) for film and molded objects. Also included are the polysulfones, polyarylethersulfones, polyaryletherketones, polyphenylene sulfides, and polyamideimides. These so-called aromatic polymers are high-performance engineering materials that compete with metals and ceramics by virtue of their light weight and easy processability.

If Sleep's predicted 10% average annual growth rate for the engineering thermoplastics materializes, West European sales in 1985 will approach 2.2 billion lb, compared to last year's nearly 1.3 billion lb. He expects, of course, a wide variation in the degree of growth among the different polymers.

Fastest growth will be in polyesters (PET and PBT combined), whose sales likely will rise 22% annually to about 675 million lb in 1985. Demand for aromatic polymers is expected to increase 13% per year to 37 million lb, polyphenylene oxides 11% to 148 million lb in the mid-1980's. Slowest growing of the engineering thermoplastics probably will be the acrylics, averaging only 4% per year to about 390 million lb in 1985.

Innovation likely will help boost the fortunes of acrylics, which have been in use for several decades. Acrylic-based composites, such as Du Pont's Corian and ICI's Asterite, have properties well outside the range of the more usual thermoplastics.

Asterite, Sleep explains, is a novel dispersion of 70% silica in methylmethacrylate. Viscosity is so low that it can be cast easily in molds to make such objects as basins, sinks, and bench tops in a wide range of colors. It combines ease of processing with properties usually associated with inorganics—rigidity, hardness, solidity, and glossy surface.

In Sleep's view, "It is unlikely that a totally new thermoplastic material will emerge as a major tonnage product during the next 20 years. This is because petrochemical monomers have all been thoroughly explored, and because of the enormous cost of launching such a product."

The newer aromatic thermoplastics are providing the best approach to materials that combine high-service-temperature characteristics with low combustibility and low levels of smoke generation in the event of a fire, together with high resistance to abrasion and solvents. Applications are developing in wire coatings, injection molded parts for motor assemblies and electronic systems. "These products at present are high-priced, low-tonnage specialties," Sleep says. "I expect to see continued innovation and growth in this sector during the next decade." □

PAC's playing bigger role in elections

Political Action Committees contributed $32 million to federal candidates in this year's campaigns, compared to $19 million in 1978

Janice R. Long
C&EN, Washington

Last week's election marked the end of a campaign period in which more money was raised and spent than at any time in U.S. history. There were at least 22 House and 15 Senate races in which each candidate received contributions totaling more than $500,000. In seven of those Senate races both candidates raised more than $1 million.

Much of the money came from Political Action Committees (PAC's)—organizations put together by corporations, labor unions, and other groups to raise funds for political candidates. These committees are becoming more and more influential in election campaigns because of the large amounts of money they have to distribute.

In the two years preceding the 1978 elections, some 1500 PAC's raised $67.8 million, spent $60.4 million, and contributed $18.7 million to federal candidates. According to the latest Federal Election Commission data, covering activity from Jan. 1, 1979 through June or August 1980, some 2600 PAC's raised $115.6 million, spent $104 million, and contributed $32.4 million to federal candidates in the 1980 election. The final figures, which will not be available until early next month, are likely to be substantially higher, since contributions usually increase during the last month of a campaign.

Of the 50 largest chemical producers in the U.S., 39 have formed PAC's. Altogether, according to the Federal Election Commission, PAC's at these 39 firms raised $2.1 million, spent $1.2 million, and contributed $885,524 to federal candidates. About 7% of that amount went to candidates in the Presidential primaries, with Republican candidates receiving five times as much as Democratic candidates. (Once an official Presidential party nominee accepts public financing, he no longer can accept private contributions.) Senate candidates received 30% and House candidates 63%; the split between Democrats and Republicans in those races was 33% to 67%.

The top money raiser among the chemical producers was the Amoco PAC, sponsored by Standard Oil (Ind.). It raised $265,600, spent $206,900 and contributed $87,900 to the candidates. Seven of the top 10 chemical producer money raisers can be considered primarily oil companies who may have had interests other than their chemical operations in mind when contributing to various candidates. The same can be said for one other member of the top 10—U.S. Steel. But Dow Chemical, which sponsors eight PAC's, is only a hair behind Amoco in its ability to raise money, a total of $264,700, and it actually contributed more, $125,000, to federal candidates.

Although chemical producers are active fundraisers, they account for just 7% of the $29.3 million raised by the 1226 corporate PAC's in the U.S., as well as 7% of the $11.8 million contributed by 890 of them to federal candidates. But the pattern of all corporate PAC contributions follows closely that of the chemical producer PAC's. Democratic candidates received 44% and Republicans 56% from all corporate PAC's. Senate candidates got 31%, House candidates 60%, and the remaining 9% was distributed among Presidential primary candidates.

The pattern is far different, as might be expected, among labor organization PAC's, which raised about $6 million less, or $23.3 million, than their corporate counterparts. Democratic candidates received 93% of the $7.7 million contributed by labor PAC's, leaving the Republicans with a mere 7%. But, as did the corporate PAC's, the labor PAC's concentrated their efforts on the House races with 67% of their contributions, compared to 31% for the Senate, and 2% for Presidential races.

The major fund raising PAC's are those sponsored by trade, membership, and medical associations, which have raised $30.9 million in this election and contributed $9.5 million to the candidates. Their contribution patterns follow closely those of the corporate PAC's, with a slightly greater edge towards Republicans.

A major new force in this year's election campaigns has been the 407 PAC's that are not affiliated with any organization. These PAC's have raised $28.6 million and spent $26.8 million. Of the $2.1 million they have contributed to federal candidates, more than 60% has been spent on efforts to defeat certain candidates.

Another new force is what the Federal Election Commission terms independent expenditures, those made without the cooperation or consent of the candidates involved. There are no limits on the amounts PAC's and individuals may spend in this way. So far, these expenditures, designed to influence the 1980 elections, have exceeded $12 million, with more than $7.5 million having been spent since Sept. 1.

More than 120 political committees, groups, and individuals made such expenditures involving about 300 candidates, and although more than $10 million was spent to promote certain candidates, at least $2 million went into efforts aimed at defeating others. Preliminary figures show that the leading independent spenders are the National Conservative Political Action Committee, $4 million; the Congressional Club, $3 million; and the Fund for a Conservative Majority, $2 million.

Not to be forgotten as a source of funds for the candidates are the political parties themselves. In addition to making direct contributions to individual candidates, the parties are allowed to spend money on their own behalf. The national Republican and Democratic party committees may each spend $4.6 million on their Presidential nominees. Party committees at both the national and state levels may spend $14,270 for each House candidate and a sum equivalent to 2 cents for each person of voting age of a state for their Senate candidate in that state.

Figures for the first 18 months of this campaign cycle show that the Republicans are much more effective at fund raising than the Democrats. During that period, the Republican

39 of the 50 largest chemical companies in U.S. have PAC's

Company	Receipts	Disbursements	Contributions to candidates: Presidential Democrat	Presidential Republican	Senate Democrat	Senate Republican	House Democrat	House Republican
Standard Oil (Ind.)	$ 265,584	$ 206,913	—	—	$ 3,000	$ 23,400	$ 16,125	$ 45,375
Dow Chemical	264,736	166,873	—	$ 1,000	4,200	33,250	25,600	60,950
Tenneco	162,364	42,800	—	—	—	15,000	2,950	18,850
U.S. Steel	128,977	80,281	—	—	7,000	13,150	17,675	22,210
Union Oil	104,944	46,333	—	12,000	3,700	6,790	3,125	14,850
Atlantic Richfield	99,839	60,502	$ 286	2,163	4,711	6,968	14,326	14,459
Standard Oil of California	76,471	35,193	—	—	1,250	3,273	9,775	10,094
Monsanto	76,100	61,347	1500	1,000	6,000	4,750	11,375	10,710
Ashland Oil	70,662	35,600	—	3,000	7,750	7,500	5,050	8,750
Texaco	67,490	34,924	—	7,500	2,150	5,550	4,225	14,750
Exxon	57,039	28,884	250	—	2,500	2,500	7,450	10,350
FMC	56,234	53,455	500	2,640	6,800	10,750	15,125	15,890
Diamond Shamrock	54,440	36,900	2000	6,200	2,700	5,250	3,350	6,900
Shell	50,261	35,800	—	—	2,700	3,500	6,775	17,160
Mobil	45,017	17,896	—	—	1,500	6,800	3,700	3,725
B. F. Goodrich	44,253	21,300	—	—	3,850	3,300	3,450	9,700
Occidental Petroleum	41,975	44,150	5000	8,000	2,500	1,500	2,150	—
American Cyanamid	38,511	24,772	—	—	2,500	4,650	3,150	12,722
Conoco	34,081	5,800	—	—	1,000	—	1,300	2,200
Akzona	33,730	17,482	—	—	1,000	5,500	1,100	9,850
Eastman Kodak	31,738	12,963	—	5,000	1,600	—	2,000	4,350
Union Carbide	30,116	23,344	—	—	1,500	750	4,050	5,900
Allied Chemical	27,310	13,237	—	—	1,650	1,100	700	3,000
NL Industries	26,526	7,900	—	500	2,000	500	1,750	100
Celanese	25,303	21,125	—	—	4,000	1,400	7,875	11,490
Hercules	24,989	6,250	—	—	250	500	3,200	2,300
Ethyl Corp.	22,568	6,494	—	—	2,000	1,000	500	2,650
Stauffer Chemical	21,810	7,217	—	—	1,500	1,300	2,250	2,385
Williams Cos.	21,205	9,037	250	250	1,250	1,750	2,312	1,725
International Minerals	20,142	13,400	—	—	4,000	3,000	3,300	3,100
PPG Industries	18,221	2,775	—	500	250	700	—	1,000
Dow Corning	14,127	1,350	—	—	—	—	—	1,150
Rohm & Haas	12,217	12,650	—	—	700	100	500	7,100
Borg Warner	11,992	7,102	—	—	—	2,000	450	4,350
Phillips Petroleum	10,266	—	—	—	—	—	—	—
Ciba-Geigy	8,300	8,650	—	—	750	400	2,675	4,825
Air Products & Chemicals	4,766	—	—	—	—	—	—	—
W. R. Grace	4,045	4,725	—	—	1,300	400	1,600	925
Borden	3,745	2,500	—	—	—	400	1,000	—
TOTAL	$2,112,364	$1,217,924	$9786	$49,753	$89,561	$178,681	$191,938	$365,845

Note: Figures are for January 1979–August 1980.

Party raised $96.1 million and spent $83.1 million, whereas the Democrats raised only $17.5 million and spent $15.5 million. Democratic Party committees have contributed $445,230 to their candidates and have spent $163,779 on their behalf; Republican party committees contributed $2.2 million to candidates and have spent $1.5 million in conjunction with general election campaigns.

Both parties have contributed more to incumbents than to challengers. Democratic incumbents received 67% of their party's contributions, challengers 5%, and candidates running for open seats 17%. Republican incumbents received 45% of their party's contributions, challengers 36%, and candidates running for open seats 19% (but then they have more challengers than incumbents).

This tendency to favor incumbents and thus the status quo also holds true for most PAC sponsoring organizations. Corporate PAC's directed 70% of their contributions to incumbents, labor PAC's 76%, and those associated with trade and membership organizations 74%. Only the nonaffiliated PAC's bucked this trend, directing 44% of their contributions to challengers and 37% to incumbents. The remaining percentages in all cases went to candidates running for an open Senate or House seat.

PAC's operate by soliciting voluntary contributions from an organization's employees, stockholders, and members. Currently PAC's can contribute up to $5000 to a candidate for each election (primary, runoff, or general). They also can make nonmonetary contributions to a candidate's race, such as sponsoring mass mailings or operating phone banks. Funds left over at the end of any two-year election cycle can be carried over into the next cycle. □

NOTE

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Chemical & Engineering NEWS

Cover: Corpus Christi Petrochemical Co.'s new 1.2 billion lb-per-year ethylene plant at Corpus Christi, Tex. Photo by Don Pate—Compix Photo

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Slow recovery begins for petrochemicals

Following thorough drubbing in 1980, basic olefins and aromatics output is picking up, but capacity use and profits will stay low in 1981

Basic U.S. petrochemicals are on the recovery side of the second major profit shock in five years. The upswing began during the third quarter of 1980, faltered a bit as the fourth quarter opened, and appears to be regaining strength now.

Early 1981 again may be slow because of the effects of the recent rapid rise in interest rates and continuation of a high inflation rate. However, the second half of 1981 could pull production back to 1979 rates, industry people hope.

These uncertainties for petrochemicals are a mirror image of uncertainties a year ago. At that time, the depth and duration of a long-expected business downturn were the big questions for 1981. The answers came in blinding clarity with the recession in the second quarter, which pulled petrochemical performance for 1980 way below even conservative earlier estimates (C&EN, Nov. 19, 1979, page 10).

Production this year falls short of forecasts by 13% for the five leading basic olefins and aromatics covered in the following pages—ethylene, propylene, butadiene, benzene, and *p*-xylene. Their combined output of 58.5 billion lb in 1980 is also 9% below production of 64.3 billion lb in 1979.

The average unweighted price per pound for these chemicals has increased 26% in 1980 to 24 cents a lb. However, the output decline is holding total production value to $13.2 billion, a 22% gain from 1979. Profits have fallen hard.

It has become doubly clear from this slump that petrochemicals are products to be handled only by the strong, preferably a multinational company with good connections to raw material oil and natural gas. Petrochemical profits at large producers tumbled at rates sometimes exceeding $100 million per year in the third quarter, probably the worst period. In C&EN's third-quarter petrochemical profits survey (C&EN, Nov. 10, page 15), combined earnings for these companies declined 68% from third-quarter 1979. This plunge was more than four times the 15% overall profits drop for basic chemical companies for the same period.

It would be nice if petrochemicals could bounce back in six months to a year from this financial pit. But petrochemicals tend not to act that way, and conditions in 1981 are not promising.

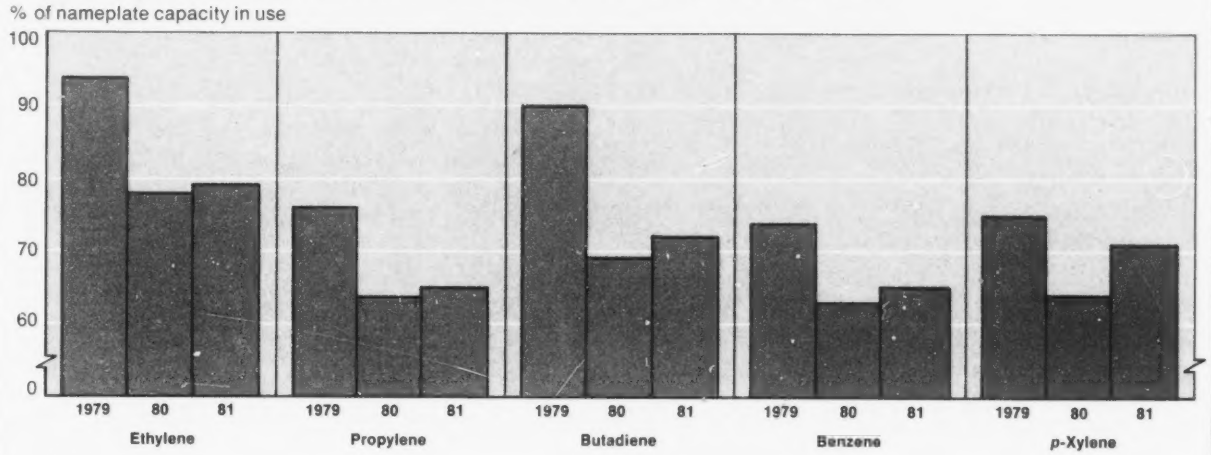
If industry optimists are right, output may well recover almost completely to prerecession levels. But that won't be enough in the face of increased plant capacity and ever higher feedstock costs, by far the most important fact of economic life for petrochemicals.

Specifically, combined output of these five major petrochemicals is expected to rise 11% in 1981 to 64.9 billion lb, about equal to 1979 output. Unfortunately, plant capacity at the start of 1981 will be 17% higher than in 1979 at 89.9 billion lb per year. That bodes an average nameplate capacity use in 1981 of 72%, not much higher than the profit-sapping 70% rate in 1980 and far below the prosperous 84% level of 1979.

Producers accept this slow start for 1981 and are thinking much farther ahead in their investment planning. For now, no new capacity appears needed for at least two years. But capacity planning, a worldwide consideration these days, takes longer than that. In their mulling for the mid-1980's producers are up against more brand new possibilities, including a large flow of funds for simple ethane crackers in foreign natural gas fields.

Bruce Greek, Houston, and William Fallwell, New York

Capacity use in major petrochemicals will recover only slightly in 1981



Sources: Industry, C&EN estimates

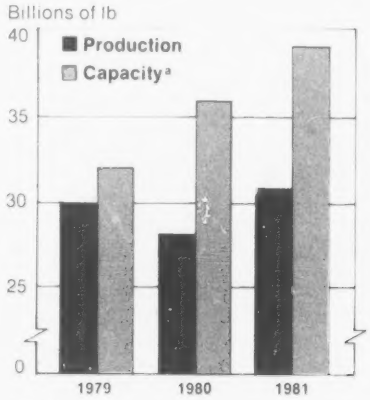
Key Chemicals

$CH_2{=}CH_2$

Ethylene

- ***Demand recovering***
- ***Capacity rising***
- ***Prices headed up***

PRODUCTION/CAPACITY



a As of first quarter

HOW MADE

Thermal (steam) or catalytic cracking of hydrocarbons ranging from natural gas-derived ethane to oil-derived gas oil (fuel oil)

MAJOR DERIVATIVES

Polyethylenes 45%, ethylene oxide 20%, vinyl chloride 15%, styrene 10%

MAJOR END USES

Fabricated plastics 65%, antifreeze 10%, fibers 5%, solvents 5%

FOREIGN TRADE

Negligible

PRICES

22 to 23 cents per lb after discount

COMMERCIAL VALUE

$6.25 billion for total 1980 production

U.S. ethylene producers are looking back on a year that was bad enough but could have been even worse. The year brought severe cuts in production for several months and then a modest recovery. The outlook for 1981 is further recovery in production and demand to just over 1979 levels.

For 1980, ethylene production in the U.S. will do well to top 28 billion lb. Many industry sources don't expect production to do that well and predict a drop of about 10% from estimated 1979 production of close to 30 billion lb. A few people, expecting possible setbacks in output this month and next, predict 1980 production could be as low as 26.5 billion lb.

Unfortunately, plant capacity gained strongly during the year. Operable—but not necessarily operating—capacity reached 36 billion lb as the year opened, up about 4 billion lb from early 1979. During 1980, additional capacity came on stream totaling 3 billion lb or 8.5% of the in-place capacity. More new capacity now is going through startup.

The average operating rate for ethylene producers in 1980 fell to less than 80% of nameplate capacity. By contrast, the 1979 average operating rate was about 90%, the top effective rate for the industry. For 1981, the operating rate might average about the same as in 1980, since expected demand for ethylene will rise proportionately about the same as capacity additions in 1980.

The relatively low operating rate for ethylene producers in 1980 can be viewed several ways. To some degree, a lower rate was forced upon the producers by their all-out production in 1979. Some producers anticipated that 1980 would be a recession year, following a very good 1979. So they delayed plant maintenance as long as possible to take advantage of strong demand and to serve all customers.

In 1980, these producers were forced into plant shutdowns that couldn't be delayed any longer. Such planned shutdowns in an average year account for about 10% of production time—roughly a month's production loss. To be generous, the 1980 maintenance shutdowns might have taken out 15% of the year's capacity for various technical reasons relating to the previous long production runs.

Average capacity use, however, fell below 80% in 1980. This means that some plants operated for long periods at levels below the practical economic breakeven point and that others shut down for longer than usual maintenance.

Production data this summer show how the industry reacted to slumping demand. June production was at an annual rate of 25.7 billion lb, July production was just under 23 billion lb, and August production, the latest month for which data are available from the U.S. International Trade Commission, was 22.5 billion lb, possibly the nadir in 1980.

For 1981, even with the inherent inventory building associated with new capacity, recovery from the production low point in third-quarter 1980 likely will be slow. The rate is expected to speed up about midyear. If so, the second half of 1981 will provide the gains needed to bring production back over 1979 levels. Of course, even if 1981 ethylene production does top 1979 production slightly, it will mean effectively a two-year pause in growth. At the same time, capacity will have risen more than 20%. This promises a not very profitable time for ethylene producers, although perhaps a better period than the earnings disaster in the third quarter. Such an outlook for the next year should certainly put a clamp on proposals for money to build new capacity, even if the money is available.

The recent slump in ethylene production directly reflected slumping demand for derivatives. Some of these, notably polyvinyl chloride, were hit by the recession worse than ethylene, as construction and other markets faltered.

None of the changes in derivative demand during 1980 have been large enough to change the overall end-use pattern of ethylene significantly. The recovery in derivatives isn't expected to do so either.

Ethylene prices fell during 1980 when demand softened from a posted high of 24.5 cents a lb in April to as low as 20 cents a lb on the thin spot market this summer. Now most industry sources expect prices to climb as feedstock prices increase. The guess is a tab of 26 cents this winter with possibly a 2-cent discount.

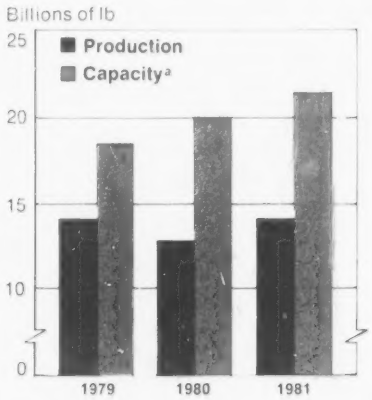
Key Chemicals

$CH_2{=}CH{-}CH_3$

Propylene

- ***Demand better***
- ***Capacity up***
- ***Prices to go up***

PRODUCTION/CAPACITY



a As of first quarter

HOW MADE

Recovered from cracked gas streams of oil refineries, coproduct streams of steam-cracking olefins plants

MAJOR DERIVATIVES

Polypropylene 25%, acrylonitrile 15%, isopropyl alcohol 10%, propylene oxide 10%

MAJOR END USES

Fabricated plastics 50%, fibers 15%

FOREIGN TRADE

Exports—negligible; imports—small, less than 500 million lb

PRICES

Polymer grade—18 cents per lb, chemical grade—about 1 cent less

COMMERCIAL VALUE

$2.5 billion for total 1980 production

Propylene has come through some shaky times in the past several months. Demand has been met, sometimes with a bit left over and sometimes with propylene taken from inventory. Prices suffered at first as derivatives production was slashed to cut inventories, but now prices have recovered pretty much to contract levels.

Such are the consequences of propylene's peculiar coproduct position. When ethylene demand falls off, multiple-product steam crackers are operated at lower levels, dropping production of propylene as well. Similarly, at refineries, the other main propylene source, when gasoline demand falls and refinery operations are reduced, fluidized-bed catalytic cracking units produce less propylene as coproduct with other heavier olefins.

These conditions are converging to cause a drop in combined polymer and chemical grades of propylene production in 1980 of about 10% to about 12.8 billion lb from estimated 1979 production of 14 billion lb. If the U.S. economy improves strongly in second-half 1981, production of both kinds of propylene likely will again reach the 1979 level.

Provided demand holds up for propylene at reasonable prices, this coproduct situation will allow production high enough to meet demand but no higher unless inventory building gets involved. Plenty of plant capacity exists to make propylene, particularly in those refineries that have the facilities to purify propylene to necessary specifications.

In most circumstances, coproduct propylene from steam cracking operations also is purified and used to make derivatives instead of fuels. The reason is that companies owning steam crackers also make derivatives, which they can sell for better prices than for gasoline.

With crude oil prices increasing relatively rapidly, operators of steam crackers are running as much lighter raw materials as possible—ethane and propane, for example. Under such substitution, coproduct propylene output falls. Demand for polymer- and chemical-grade propylene in these situations is usually met by augmenting steam cracker production with refinery-produced propylene.

However, earlier this fall, refinery operations were reduced to an average of under 70% of capacity, lowering propylene availability. The resulting squeeze was not severe on propylene for polymers and chemicals. However, it did tend to firm up propylene prices, which had fallen more than ethylene prices during the summer.

In effect, the lowered output of propylene in steam crackers has helped to restore the traditional price spread between these two basic olefins. Currently, producers are comfortable with prices for polymer-grade propylene of about 80% of ethylene prices.

The conventional price ratio between propylene and ethylene is expected to hold for some time in 1981 unless drastic changes occur in the economy. Although derivatives demand will continue to grow slowly for both olefins, price changes will result more from feedstock cost increases than from demand growth.

For propylene, the big capacity growth at steam crackers is not expected to cut prices. Estimates of new capacity for propylene can be fairly accurately determined with assumptions for ethylene capacity and the kind of feedstock. These increases are pushing up total U.S. propylene capacity to 21.5 billion lb per year in first-quarter 1981 from 20.0 billion lb a year earlier.

However, estimates of propylene capacity in refineries are fuzzier because more variables crop up in crude oil type, cracking catalysts, and so on. Overcapacity at refineries for polymer- and chemical-grade propylene has been the rule for years, but exactly how much effective capacity there is remains open to argument.

This year's steam-cracker propylene capacity growth exceeds the expected demand growth next year without any capacity additions from refineries. In 1981, the result will be that propylene at steam crackers will be guided as usual by ethylene production.

In 1980 and 1981, propylene's production and pricing shifts will have no noticeable effect on derivatives' production or end-use pattern. Export changes, especially in polypropylene, might be large, but nowhere large enough to affect the fraction of propylene going to make polypropylene.

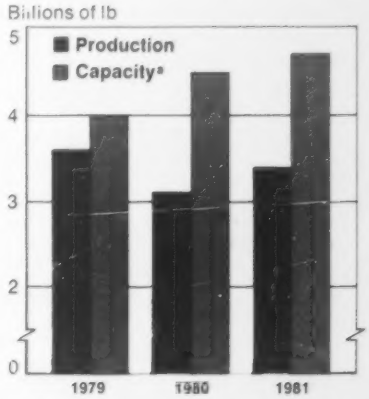
Key Chemicals

$CH_2{=}CH{-}CH{=}CH_2$

Butadiene

- ***Demand shifting up***
- ***Supply tight***
- ***Prices firming***

PRODUCTION/CAPACITY



a As of first quarter. Combined capacity for dehydrogenation and extraction.

HOW MADE

Recovery from coproduct streams at steam-cracking olefins plants; dehydrogenation of butylenes or butane from refineries and natural gas

MAJOR DERIVATIVES

Styrene-butadiene rubber 50%, polybutadiene rubber 20%, hexamethylenediamine 10%

MAJOR END USES

Rubber products 80%, fibers 10%

FOREIGN TRADE

Exports—about 100 million lb, imports—rising to 500 million lb

PRICES

Contract—32 cents per lb discounted

COMMERCIAL VALUE

$1 billion for total 1980 production

Butadiene, alone among the major basic olefins, has moved into a position of short supply. This may seem like a strange state of affairs for a product whose dominant use is in the ailing rubber industry. But by special butadiene logic, it all adds up.

Currently, butadiene prices haven't gone back up after dropping from recently higher prices, but temporary voluntary allowances (discounts) may fall away soon. The spot market has just about disappeared because supply limitations have cut off butadiene beyond contract volumes.

This snug situation is hardly hinted by butadiene production this year, which probably will have decreased 14% from 1979 to 3.1 billion lb by year's end. Capacity use has averaged 69% this year, based on 4.5 billion lb per year of nameplate plant capacity in place at the beginning of the year. For 1981, production is expected to reach 3.4 billion lb from 4.7 billion lb of capacity.

Behind the rapid switch from oversupply of butadiene in early summer to the current tight situation are storage capacity, limitations in steam cracker output, and imports. Butadiene storage capacity in the U.S. amounts to a bit more than 1% of production capacity, compared to 3 to 5% for ethylene. Limiting storage capacity is butadiene's reactive nature, which requires refrigerated storage and thus reduces producers' incentives to build and maintain such facilities.

In effect, most butadiene is stored as derivatives, mainly as finished rubber and rubber products. And in the past 18 months demand for rubber products has been low because of the crippled state of the automobile industry. Thus, tire inventories have built up, and several tire and rubber plants have shut down because of reduced rubber demands.

Consequently, butadiene demand fell. Prices eased, especially on the spot market, and temporary voluntary allowances popped up. With the financial return from coproduct butadiene production in steam crackers reduced, operators had increased difficulty in profitability.

As they did with propylene, these operators shifted feedstock makeup as much as possible toward less costly materials, mainly lighter hydrocarbons from natural gas rather than gas oils or naphtha from high-priced crude oil. This shift to lighter feedstocks reduced coproduct butadiene production significantly.

At the same time, butadiene output in Western Europe and Japan remained constant or fell. Japan is believed to even have imported some butadiene, thereby reducing the amount available on the world market. This reduction in non-U.S. supply means less available for import to the U.S. In recent years, the U.S. has imported 10 to 20% of its butadiene supply, mostly from Western Europe.

This year, butadiene imports will be up over last year, if fourth-quarter imports about equal those in the third quarter. However, imports in both quarters will be lower than those in the first two quarters. They aren't likely to be enough to meet extra demand now that many, if not all, of the shut-down synthetic rubber plants have been restarted.

The price scenario for butadiene from now on calls for an end to the 2-cent allowances by the end of the year, bringing the price to 33 to 34 cents a lb on contract. Prices are expected to rise at the start of 1981. The increases possibly will be 2 or 3 cents, tempered with allowances that could be removed later in the quarter.

The instability of butadiene prices and its reduced output in 1980 reflect its long-time problem of high dependence on the auto industry. Products used in transportation account for three fourths of butadiene consumption in the U.S. In the past several years, rubber demand has grown only about 1 to 2% annually. In this recession year, a decline is likely. Longer term, these small growth rates will continue as tires improve in quality with longer average life and less rubber per unit.

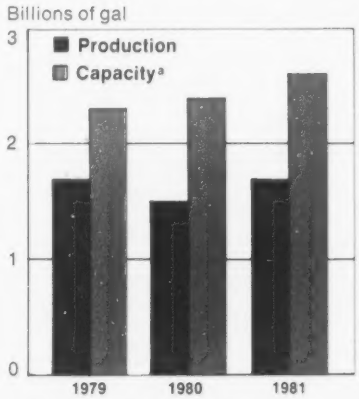
Efforts continue to seek other products that can be made from this reactive molecule, but so far such products have been few. For the rest of this year, next year, and for several years beyond, butadiene will have to ride with the uncertain fortunes of the transportation industry. That means more quirks in supply and pricing, which will seem to defy the obvious conclusions from capacity and demand.

Key Chemicals

Benzene

- ***Demand better***
- ***Capacity up slightly***
- ***Prices due way up***

PRODUCTION/CAPACITY



a As of first quarter.

HOW MADE

Extracted from catalytic reformate made in oil refineries, from pyrolysis gasoline made in steam-cracking olefins plants, and from light oils in coking coal; dealkylation of toluene

MAJOR DERIVATIVES

Ethylbenzene 50%, cumene 15%, cyclohexane 15%, aniline 5%

MAJOR END USES

Polystyrene 25%, nylon 20%, other styrenic polymers 10%, rubber 5%

FOREIGN TRADE

Exports and imports small

PRICES

Contract—$1.60 to $1.70 per gal

COMMERCIAL VALUE

$2.5 billion for total 1980 production

Benzene producers and marketers are looking at a much more active market than they did a few months ago. Although the business may not be more profitable, it flashes a hopeful sign for all basic chemicals, since benzene tends to move ahead of the main chemical business cycle. That is, it gets into trouble early in a recession but pulls out early too.

In the recession now apparently ended, benzene suffered as much as any basic chemical and more than many. Production for 1980 probably will be down 12% to 1.5 billion gal from 1979. In 1981, a strong recovery in the second half could push production back to the 1979 level of 1.7 billion gal.

In 1980, annual nameplate capacity for benzene has risen 200 million gal or so, about equal to the increase in production expected for next year. Most of the new capacity is at olefins-producing steam crackers that came on stream this year. Total U.S. capacity will increase to 2.6 billion gal per year in first-quarter 1981 from 2.4 billion gal a year earlier.

The operating rate for 1980 fell to a bit more than 60% of capacity, well below typical rates of recent years in the low 70%'s. The rate will be up in 1981 but not back to 70%.

These operating rates, considerably below the usual in chemicals, mean less than do many others. In making benzene, capacity seldom is strained, but less capacity is really there many times than official figures indicate. The extra capacity acts as a profit buffer to hold down rapid swings from good to bad or vice versa.

For example, capacity for benzene via dealkylation of toluene is reported as if all necessary toluene were available to make competitively priced benzene. However, many times, for example in early November, the price of toluene is too high for profitable operation of a dealkylation unit after consideration for the cost of raw material hydrogen and the loss of a methyl group from toluene.

The interplay of toluene and benzene prices is mainly influenced by the gasoline market. High pump prices earlier this year for gasoline, leading to reduced consumption, caused gasoline marketers to look for ways to bolster sagging profits. The answer was better gasoline sold at a higher price for a bit better profit. Hence this summer there was a rush to premium unleaded gasoline with a higher octane value to combat engine knock. This move meant greater demand for toluene with its high octane rating. It also swept up some of the mixed xylenes available in refinery reformates.

Toluene prices increased to $1.40 a gal from the earlier depressed $1.15 or so, whereas benzene prices slid because of slack demand for styrene and other derivatives. At this new price level, toluene cost just a little less than benzene, whose spot sales had dropped to $1.45. Dealkylation was out.

Now the situation is changing for these aromatics. Although the premium unleaded gasolines did well, autumn isn't the peak time to sell gasoline, and the pipeline between refinery and service station is now reasonably well filled. So demand for toluene has slowed, and prices have weakened.

However, all raw material hydrocarbon prices likely will be increasing, and demand for benzene derivatives has begun to recover. At a time like this, good management calls for some inventory building in benzene and derivatives to avoid higher costs. This is just what is happening now. As a result, benzene prices have risen to about $1.70 a gal and are forecast to go higher in early 1981.

Although every producer has slightly different economics, the price spread between benzene and toluene might bring dealkylation units back into operation. If benzene reaches $1.80 a gal and toluene falls to $1.30, the 50-cent spread might be enough to justify dealkylation on a marginal basis. Operators then must judge how long the spread will hold, or what it will grow to, so that they can recover the costs of restarting the units. Each case is different, but few units are run for less than three months and most for at least six months.

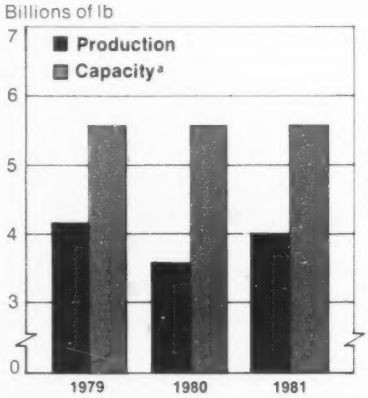
Some overlap must occur. Dealkylation units won't all be started up at the same time. Even with plentiful toluene at relatively low cost, tightness in benzene supply could occur at times in 1981. If it develops, it would spur more dealkylation and a more rapid correction.

Key Chemicals

p-Xylene

- ***Demand up slightly***
- ***Capacity flat***
- ***Prices steadying***

PRODUCTION/CAPACITY



a As of first quarter.

HOW MADE

Separated from mixed xylenes made in oil refineries or from pyrolysis gasoline made in steam-cracking olefins plants

MAJOR DERIVATIVES

Dimethyl terephthalate 50%, terephthalic acid 50%

MAJOR END USES

Polyester fiber, film, and fabricated items, mostly bottles, 100%

FOREIGN TRADE

Exports—more than 800 million lb in 1980, imports—negligible

PRICES

Contract—27 cents per lb

COMMERCIAL VALUE

$900 million for total 1980 production

If you thought last year was bad for *p*-xylene, take a look at this year. The production rate has dropped faster than in 1979. Although capacity hasn't risen, capacity use has averaged a low 64%. Chalk up a very poor 12 months.

Until recently, *p*-xylene had only one important end use—polyester fiber. Polyester film has been around for some time now but its use hasn't reached even 10% of the total film market in recent years. Polyester bottles are gaining acceptance fast but have encountered some stumbling blocks to their development as a big end use of *p*-xylene. Their growth rate has fallen below some optimistic forecasts.

With a big end market in the textile industry, *p*-xylene flies through some of the same swings in demand as in apparel and other textile products. Recessions tend to hit textiles and *p*-xylene hard, and the most recent recession was no exception.

In 1980, production of *p*-xylene will amount to about 3.6 billion lb, down about 16% from 1979. Next year, recovery is likely, with output up 16% to about 4.0 billion lb. This means that *p*-xylene will take until 1982 to exceed the previous peak production of 1979, suffering a delay matched only by butadiene among leading basic petrochemicals.

The best thing that can be said about *p*-xylene this year is that no new capacity has or will come on stream. For *p*-xylene, where good news is quite relative, that's at least something. *p*-Xylene has had substantial overcapacity for the past five years, ranging between 20 and 40%. Current nameplate capacity is 5.6 billion lb per year.

For the future, too, *p*-xylene producers have no capacity additions planned or even rumored. Therefore, even with growth rates averaging a stately 5% per year, production can get much closer to capacity again without the depressing impact of new plants on pricing. By 1985, capacity use could become as high as for most other chemicals.

A faster growth rate still might occur for *p*-xylene. At least for now, the slump in polyester fiber seems to be over. Production in the fourth quarter has continued to improve following a pickup in September.

Polyester bottles, especially for soft drinks, became a booming market last year. Starting from a small base, the growth rate in demand for *p*-xylene going into this use ran from 25 to 50% per year. Some industry sources cite limits in bottle-making capacity as the rate controller in this market. Last year, the large-size bottle market for soda apparently was conquered. The drive into smaller-size bottles began. Again, bottle-making capacity is cited as a reason for unexpectedly slow penetration, but industry sources also emphasize competition by glass and metal container producers.

Given official overcapacity in *p*-xylene, a sudden surge in demand would seem to be handled easily. However, feedstocks could tighten this spring if competing gasoline demand picks up, carrying demand for premium unleaded gasoline along with it. Next to toluene, the mixed xylenes stream at refineries and olefins plants is the favorite octane booster among aromatics.

During late summer, when various gasoline marketers moved their premium unleaded brands to the public and toluene prices rose, mixed xylene prices tagged along. Then when the Iraq-Iran war broke out, prices rose again, and the spot price of *p*-xylene began to firm. Although the volume of spot *p*-xylene is small, its price has come up nearly to the contract level. Still, *p*-xylene's price remains the weakest of the major basic petrochemicals, up only a penny to 27 cents a lb in the past year.

The same conditions have affected *p*-xylene's kin, *o*-xylene, the other xylene isomer of major commercial importance in the U.S. In spite of sliding demand for phthalic anhydride—the predominant outlet for *o*-xylene as an intermediate for plasticizers used in vinyl plastics—the spot price for *o*-xylene also has moved close to the contract price.

Exports of both of these xylene isomers are large relative to production. Because of lower U.S. hydrocarbon costs, the financial return from exports has held up pretty well, even with competitive pressures from foreign producers which face the beginning of a recession in Europe. Slippage in exports could reduce U.S. production of these isomers in 1981, but the expected improvement in the U.S. economy could offset this decline.

Good growth forecast for fire retardants

In spite of the recent controversy over fire retardants, or perhaps because of it, the market for fire-retardant and smoke-suppressant (FRSS) chemicals is expected to perform very well over the next five years.

Business Communications Co., a Stamford, Conn.-based consulting firm, says that consumption of flame retardants and smoke suppressants will increase to 1 billion lb in 1985 from about 694 million lb in 1980, an 8% average annual growth rate.

According to BCC in a recently published report, total consumption for all flame-retardant chemicals 15 years ago was about 120 million lb per year. Estimates for 1975 put consumption at about 400 million lb per year. Thus, BCC says, flame-retardant chemistry did not come of age until about 10 years ago.

The consulting firm says that markets for the chemicals also may be boosted by regulatory activity. Legislation, plus normal market expansion, will help increase demand through the next half-decade.

The fastest growing FRSS chemicals will be those that are bromine based. However, because of the relatively low amounts of the bromine-based chemicals used, the predicted 11.4% annual increase in their production will not affect total FRSS demand until about 1990.

The biggest growth among the large-volume FRSS chemicals will be for phosphorus-based compounds. BCC predicts these will grow at an annual rate of 10.4% over the next five years to about 348 million lb per year. The consulting group says that phosphorus has the most fully developed flame-retardant chemistry.

Fire and smoke chemicals' use to rise 8% annually

Millions of lb	1980	1985	% annual change 1980–85
Antimony trioxide and related antimony chemicals	31	39	4.7%
Aluminum trihydrate	300	421	7.0
Phosphorus based	211	348	10.4
Bromine based	32	55	11.4
Chlorine based	80	102	5.0
Boron and miscellaneous	40	51	5.0
TOTAL	694	1016	7.9%

Source: Business Communications Co.

Presently, aluminum trihydrate is the most important of the fire-retardant chemicals in terms of poundage used at about 300 million lb per year. However, it has one of the lower growth rates of the top-volume FRSS chemicals surveyed by BCC. Thus aluminum trihydrate will begin to lose ground to the phosphorus-based chemicals. If the current trend continues through 1990, aluminum trihydrate will become the second-place fire-retardant chemical.

Use of the other major fire-retardant chemicals—antimony trioxide, chlorine-based compounds, boron, and others—will grow at about 5% annually through 1985.

The survey predicts that most of the growth for FRSS chemicals will be in plastics, although the plastics boom is beginning to slow, according to the firm. Plastics presently take about 60% of FRSS demand. Textiles are second with about 32%.

The study also cites wire coatings and foam insulation, both plastics applications, as new markets which will keep plastics the leading user of FRSS chemicals. □

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Canadian chemical slowdown continues

Despite higher sales, profits fell for two of four largest firms in first nine months; Du Pont Canada was hardest hit, with earnings of 17%

For Canada's four largest publicly reporting chemical companies, the first nine months of 1980 brought mixed results. Although C-I-L Inc. and Union Carbide Canada could boast of substantial increases in net income, Celanese Canada and Du Pont Canada suffered modest declines. Total sales for the four firms amounted to $2.32 billion (Canadian), up 12.6% from the first nine months of 1979. Total earnings came to $149.6 million, a 22.3% increase.

Most of the improvement was confined to the first six months, however. In the third quarter, sales totaled $739.0 million, only 5.4% better than in 1979's third quarter. During the same period, net income fell 21.2%, to $40.8 million. Profit margins ranged from 3.0 to 10.0%, an average 5.5%, compared to an average 7.5% in the third quarter of 1979.

Only C-I-L managed to buck the trend both in the third quarter and the first nine months. The company had third-quarter sales of $231.8 million, a 12.0% increase from 1979's third-quarter figure. But earnings rose 35.5%, to $12.0 million. For the nine-month period, C-I-L sales rose 12.3%, to $741.9 million, while net income went up a healthy 39.9%, to $41.0 million.

Despite the general slowdown in the Canadian economy, key industries that C-I-L serves, including mining, agriculture, and pulp and paper, have remained relatively buoyant, the company says. At the same time, improved operating efficiencies more than offset higher costs for labor and raw materials. C-I-L expects that full-year earnings will be significantly higher than in 1979.

The same can't be said for those companies with heavy involvements in fibers and textiles. At Celanese Canada, for example, the earnings drop had already begun in the second quarter, and it got worse in the third. Although third-quarter sales reached $89.6 million, a 12.6% increase from the like period last year, earnings fell 21.2% to $3.4 million, representing only a 3.8% return on sales. The company's polyester/polypropylene and carpets businesses continued to show losses, while earnings fell slightly in chemicals and sharply in cellulosics. Only Celanese's industrial products business showed a gain.

For the first nine months, Celanese's sales amounted to $289.3 million, up 13.6% from the like period in 1979. Earnings during the period came to $14.1 million, a 9.6% decrease.

Things were even worse at Du Pont Canada. Third-quarter sales amounted to $234.3 million—only a 2.1% increase in terms of revenues and an actual decline in terms of volume. Earnings came to $7.1 million, a precipitous 61.0% drop from last year's third quarter. Return on sales sagged to 3.0% compared to 8.0% in the third quarter of 1979.

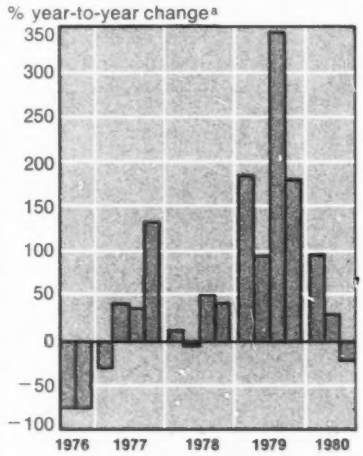
For the first nine months, Du Pont had sales of $716.6 million, a 10.9% increase from the like period in 1979. Earnings totaled $33.3 million, a decline of 16.8%. Du Pont notes that export sales came to more than $100 million in the period, a 26% increase from 1979; however, domestic sales reflected the impact of slow business conditions.

Union Carbide Canada's sales and earnings both fell in the third quarter. Sales amounted to $183.3 million, down 1.1% from the third quarter of 1979. Earnings for the period fell 9.6% to $18.3 million; the percentage drop would have been worse except for changes in accounting procedures. Nevertheless, the company's third-quarter profit margin was still a respectable 10.0%.

Carbide had a very good first half, so the figures for the first nine months look considerably better; sales of $567.3 million (up 14.8% from the first nine months of 1979) and net income of $61.2 million (up 63.5%). Again, part of the apparent earnings increase was the result of accounting changes. Carbide sees signs that the recession may abate in the fourth quarter; it expects full-year earnings to exceed 1979's, even without the accounting changes.

Ward Worthy, Chicago

Combined earnings drop 21% in third quarter



a After-tax earnings of four largest publicly reporting Canadian chemical companies—Celanese Canada, C-I-L, Du Pont Canada, and Union Carbide Canada.

Mixed results for Canada's four biggest chemical firms

	NINE-MONTHS 1980					
$ Millions (Canadian)	Net sales	Change from 1979	Net income	Change from 1979	Profit margin[a] 1979	Profit margin[a] 1980
C-I-L Inc.	$ 741.9	12%	$ 41.0	40%	5.5%	4.4%
Celanese Canada	289.3	14	14.1	−10	4.9	6.3
Du Pont Canada	716.6	11	33.3	−17	4.6	6.3
Union Carbide Canada	567.3	15	61.2	64	10.8	7.6
TOTAL	**$2315.1**	**13%**	**$149.6**	**22%**	**6.5%**	**6.0%**

a Net income as percentage of sales.

Steady growth ahead for methanol in Europe

"Methanol is proving to be one of the [chemical] industry's most dynamic and varied products," observes Brinsley Sheridan of Chem Systems International's London office. At a conservative estimate, its use in Western Europe as a chemicals source should grow more than 5% annually beyond last year's level to reach almost 12.4 billion lb in 1990.

Several developments could boost demand even higher. One is the direct addition of methanol to gasoline. Another is its use to produce ethylene and related lower olefins and downstream products. In any event, West European demand will outpace methanol supply in Western Europe in the foreseeable future.

Sheridan presented his views at the recent meeting of the European Chemical Marketing Research Association in Estoril, Portugal. His associate, Martin B. Sherwin, collaborated with him in the market forecast.

The burgeoning demand for methanol in newly developed uses illustrates well the dynamic nature of the market for the chemical. In 1979, for example, 719 million lb, 10% of its use in Western Europe that year, went into outlets that had developed since 1975. By 1990, these outlets likely will absorb 3.6 billion lb, just about a third of that year's projected total. Put another way, whereas the more conventional chemical outlets for methanol probably will foster a growth of just under 3% annually between 1979 and 1990, recently emerging uses are expected to spur demand by an annual rate of almost 16% over the same period.

Formaldehyde, made by catalytic oxidation of methanol, continues to be the largest single use of the alcohol. West European production of nearly 3.5 billion lb last year accounted for almost 50% of consumption. Annual growth is likely to advance at a pedestrian 2.5% rate to about 4.6 billion lb in 1990, or 37% of total methanol consumed in Western Europe in that year. Formaldehyde goes largely to make thermoset resins.

The other conventional methanol outlets center mainly on production of dimethyl terephthalate, methyl methacrylate, methyl halides, and methyl amines. Together, these accounted for slightly more than 16% (less than 1.2 billion lb) consumed last year. The share could slip to 13% (1.6 billion lb) by 1990. In addition, methanol, of course, goes into a variety of products such as solvents and various methyl esters.

The newer markets include methyl *tert*-butyl ether (MTBE), a replacement for lead-based gasoline antiknock agents, and use as an MTBE-gasoline blending agent. It also is being added directly to gasoline, and is used for production of acetic acid and single-cell protein (SCP). Acetic acid and SCP will foster fast growth in future consumption.

The amount going into acetic acid production in Western Europe will be about 1.2 billion lb in 1990, according to Sheridan and Sherwin. That represents an annual growth of almost 33% in the 1979–90 period.

SCP, too, is expected to provide a market for 1.2 billion lb of methanol in Western Europe by 1990. The growth rate will be a high 68% annually, because a mere 4 million lb of methanol was used for making SCP last year. Imperial Chemical Industries is the only large-scale producer. Its plant at Billingham, England, can make up to 165 million lb per year.

SCP is a collective name for products with a high protein content based on dried microorganisms. The material is offered as a soymeal and fishmeal substitute in animal and poultry feed. In ICI's case, the organism is *Methylophilus methylotrophus*, a bacterium grown in methanol containing various nutrients. ICI doesn't specify the amount of methanol involved. But Sheridan estimates that about 2 lb are required per pound of product. "Our forecast assumes the addition of new second-generation [SCP] capacity," he says.

A sizable quantity of methanol in one form or another probably will find its way into fuel for road vehicles. Apart from use for making MTBE by reaction with isobutylene, it also is blended with MTBE to improve volatility and aid engine startup at cold temperatures. Limited availability of isobutylene from refinery streams and steam crackers could hold growth in these two outlets to 12% per year.

"It is highly likely that our MTBE forecasts for Western Europe will prove low," Sheridan and Sherwin say, "owing to developments in the industry. A number of companies are developing technology for converting *n*-butylenes to isobutylene. This will essentially double the amount available from a cracker. The first of these plants could be on stream by 1983, so our methanol forecast [for MTBE-related use] for 1990 could be low by a factor of two.

"Prediction of the use of methanol that goes into low-level gasoline blending, primarily in West Germany, is difficult to make," Sheridan and Sherwin admit. "Addition of 2 or 3% by volume apparently is acceptable to all vehicles on the road with no [engine] modification." Accordingly, the Chem Systems analysts have taken a value of 440 million lb, "similar to that estimated for last year," and have assumed that consumption in this particular outlet will not grow.

Sheridan and Sherwin are by no means complacent about this projection. They note that government-sponsored studies are under way in a number of countries centering on use of 15 to 20% by volume of methanol in gasoline all the way to replacing conventional gasoline with methanol. There also are studies on the feasibility of using methanol as feedstock to produce supplemental gasoline by way of Mobil Oil's Mobil M process.

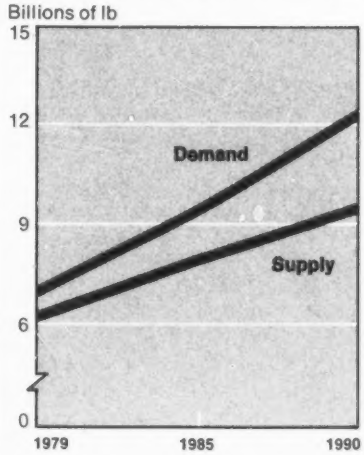
If, for example, there were widespread adoption in Western Europe of a blend containing 15% by volume, an additional 39.6 billion lb of the chemical could be needed in 1990 beyond the forecast 12.4 billion lb

Acetic acid and single-cell protein production promises to open up major new markets for methanol in Europe

Millions of lb	1979	1985	1990	% annual change 1979–85	% annual change 1979–90
Formaldehyde	3498	4048	4,576	2.5%	2.5%
Gasoline blending	440	440	440	0.0	0.0
Dimethyl terephthalate	352	407	440	2.5	2.1
Methyl amines	341	396	462	2.5	2.8
Methyl halides	242	319	385	4.7	4.3
Methyl methacrylate	242	286	330	2.8	2.9
Methyl *tert*-butyl ether	154	396	528	17	12
Methyl *tert*-butyl ether blending component	66	165	220	17	12
Acetic acid	55	572	1,210	48	32
Single-cell protein	4	352	1,210	111	68
Miscellaneous[a]	1775	2178	2,574	3.5	3.4
TOTAL	7169	9559	12,375	4.9%	5.1%

a Includes solvents and methyl esters of acetic acid, fatty acids, and glycols. Source: Chem Systems International

Nonfuel methanol demand outpaces supply in Europe

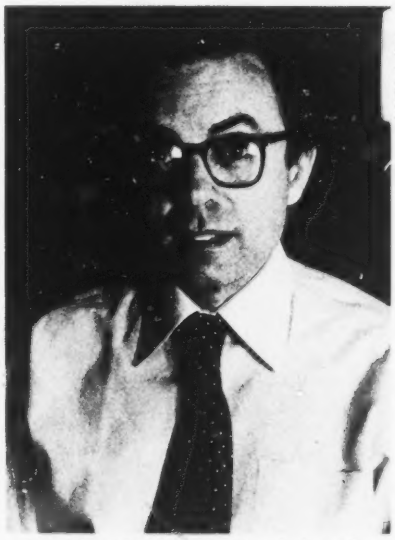


Source: Chem Systems International

demand. "It appears likely that these fuel methanol projects will require some sort of government support to launch them," Sheridan points out.

Looking into the future, he and Sherwin note a number of developments that, if they reach commercial fruition, will strengthen methanol's position further as a chemicals precursor. For example, there is growing interest in using it to produce olefins.

A number of companies are engaged in research in this area. BASF, for one, has a pilot unit at Ludwigshafen, West Germany, capable of producing 33,000 lb of ethylene monthly. The basis of this and related work elsewhere is the use of specific zeolite catalysts to convert methanol primarily to ethylene and propylene, although reaction conditions can be tailored to obtain higher olefins and aromatics.



C&EN staff photo

Sheridan: dynamic and varied product

Depending on the reaction parameters, combined ethylene and propylene yield can be as high as 70 to 80%. By comparison, the yield from a conventional naphtha cracker ranges from 44 to 50%. Temperatures involved in the methanol-to-olefins reaction are at least half as high as the 850° C needed to crack naphtha.

"Ethylene yields of 40% have been demonstrated and published," Sheridan and Sherwin note. "Fifty per cent yields probably are being realized already. And 60% ethylene yield is an attainable upper goal as the learning process continues.

"At 60% yields, the economics of the methanol-to-ethylene process would allow methanol to displace naphtha feedstock partially in Western Europe. When this is coupled with the fact that transportation use should lower methanol prices relative to naphtha, we foresee excellent prospects for commercial utilization of this technology in the future."

Apart from olefins production, the Chem Systems market researchers point to other areas where so-called C-1 chemistry holds commercial promise. Ethylene glycol might be made by reacting formaldehyde, carbon monoxide, and water to form glycolic acid, followed by esterification and reduction to the glycol.

"The technical prognosis for success of this approach is well based," Sheridan and Sherwin maintain. "It represents an improvement on commercial technology once practiced by Du Pont. Furthermore, Chevron has succeeded in reducing operating pressures while raising reaction yields. And it does not entail use of homogeneous noble metal catalysts that present extremely difficult recycle requirements.

"The economics of this route as against the conventional ethylene oxide hydrolysis has not looked favorable in a U.S. scenario. But in a West European setting, the processes are much closer to parity because of higher ethylene prices."

Of the various options involving methanol as feedstock, they believe that its use as a source of ethylene and ethylene glycol in Western Europe would be the most likely to develop commercial reality within the coming decade. If just one plant were to be built to make each of these chemicals, the annual methanol requirement would exceed 1.1 billion lb. This, coupled with a likely increase in MTBE output, could raise methanol demand in Western Europe in 1990 a further 1.4 billion lb, 11% beyond Chem Systems' base forecast. □

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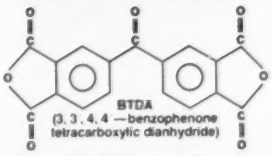

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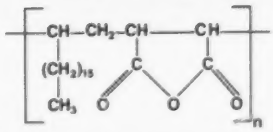

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November 24, 1980

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Cover: Mississauga (Ont.) train derailment in November 1979. Reprinted with permission of Canada Wide Features

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- ***A 500-MHz nuclear magnetic resonance spectrometer*** *begins operating at National Science Foundation lab at MIT.* ***Page 7***
- ***Robert W. Parry,*** *Distinguished Professor of Chemistry at the University of Utah, is 1981 ACS president-elect.* ***Page 7***
- ***Superfund bill*** *for cleanup of hazardous chemical waste dumps reaches Senate floor, chances of passage still slim.* ***Page 8***
- ***Patent reform legislation*** *passed by the House simplifies patent re-examination, sets standards for federal agencies.* ***Page 8***
- ***Fred A. Tate,*** *associate director for planning and development at Chemical Abstracts Service, is dead at age 60.* ***Page 8***

Business

- ***Dow Chemical prepares for 1980's expanded research push,*** *plans to be on top of wave of new R&D with novel management teams and budget increase.* ***Page 10***

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- ***Mexico's chlor-alkali industry*** *gears up to take advantage of new opportunities; new plant expected to meet much of demand for chlorine and caustic soda.* ***Page 14***

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- ***Environmentalists form coalitions*** *as result of EPA-sponsored conference; immediate concerns include Reagan's possible impact on environmental regulations.* ***Page 17***
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- ***Disasters associated with transport of chemicals,*** *such as the 1979 derailment in Mississauga, Ont., have heightened awareness of communities, generated emergency service systems.* ***Page 20***

Science

- ***The role of comets*** *in the beginnings of life on Earth discussed at University of Maryland symposium; most controversial theory propounded was that organisms evolved, and were carried to Earth, in comets.* ***Page 36***
- ***Aging of the brain*** *may not be a simple process of deterioration; rather it may be a dynamic but lawless regrowth process that becomes misdirected.* ***Page 38***
- ***Emulsion polymer yields,*** *molecular weights can be increased under certain circumstances by use of magnetic fields, research at Columbia University reveals.* ***Page 44***

Chemical transport—coping with disasters

Complexity of chemical accidents has spawned various services, such as CMA's CHEMTREC, to help communities plan for disasters and handle them when they occur

Rebecca L. Rawls
C&EN, Washington

In Toronto, they call it the "miracle of Mississauga."

Almost exactly a year ago a freight train carrying a mixed cargo including many chemicals derailed in the city of Mississauga, less than 20 miles from downtown Toronto. Among its freight were cars loaded with caustic soda, propane, chlorine, styrene, and toluene. Between midnight on Nov. 10, when the train first left its tracks, and Nov. 21, when the last fire-fighting equipment left the scene, there were three major explosions, 218,000 people were evacuated from their homes, the busiest stretch of highway in Canada was shut down, and more than 1000 emergency services personnel spent what was likely the busiest week of their lives combating what many consider the worst chemical transportation disaster that has ever occurred.

Why, then, is it called a miracle? Because most of what could have happened didn't. No one died. The fire, which at the beginning of the incident was causing a different propane tank car to explode every five minutes, was brought under control and kept there for more than a week until the danger passed. A potentially life-threatening cloud of chlorine gas was safely vented over Lake Ontario. Even the press and the disaster workers managed to keep on good terms with each other, almost a miracle in itself.

Could it have happened in the U.S.? Nearly all experts on chemical transportation and its hazards answer, unquestionably, yes. Both the incident and the way it was handled could have been duplicated in many places in this country. These experts are quick to say, however, that the same incident could have been much, much worse if it had happened anywhere but in Mississauga.

In many minds over the past year, the Mississauga incident has become the ideal of what can be done to mitigate a chemical disaster. The incident is unusual not only in how well it was handled, but in how thoroughly that handling has been recorded and made available for other groups to study. A conference in Toronto this month on "Emergency Preparedness in the 80's" focused almost entirely on this incident, and many of the hazardous materials and spills conferences of the past year have included a detailed slide presentation of the Mississauga incident.

What happened at Mississauga is attracting so much attention because transportation accidents involving chemicals are attracting much attention. As many as one truck in 10, and one freight train in three carry hazardous materials in the U.S. The public has become aware of what the chemical industry, the shippers, and the federal government have known for a long time: namely, that the millions of tons of hazardous chemicals that travel throughout the U.S. each year carry with them the potential for truly catastrophic disasters.

At first glance, this risk seems to be growing at alarming speed. The Department of Transportation received reports on 2255 transportation incidents involving hazardous materials in 1971, the first year for which such reporting was required. These reports include petroleum and other hazardous materials spills in addition to chemicals. By 1979, the number had grown nearly eightfold.

However, several factors make this increase deceptively large. Reporting is better now than it was in the early 1970's, for example, and the number of substances considered hazardous has increased greatly. Also, the volume of chemicals being shipped is about 80% greater now than it was in 1971. Just how big the increase in transportation incidents really has been over this period is difficult to say; some people close to the problem even suggest that for major accidents, the rate may not have risen at all.

C&EN staff photo

Firemen wearing protective chemical hazard suits board tugboat in simulated chemical spill cleanup on the Maumee River in Toledo, Ohio

In fact, the safety record for chemical transport is quite good. Of the 90 million shipments of hazardous materials that DOT estimates occur in the U.S. each year, 17,524 resulted in reports of unintentional materials release in 1979. Put differently, this means that 5000 shipments occur without incident for every one that has a spill. And 45% of these spills involve containers of less than 5-gal capacity.

Whittling down the number of incidents reported to the number that are actually serious is not easy. John C. Zercher, who heads the Chemical Manufacturers Association's chemical emergency information system, CHEMTREC, estimates that of the 2512 chemical spill incidents they were called about in the first nine months of this year, only 20 to 25 were serious enough to meet the federal requirements for reporting hazardous chemical discharges. And really major incidents are even less common. James C. Clow, chief of the National Response Center, the Coast Guard-run center where hazardous discharges are reported, says only five or six incidents a year require calling in the full federal resources to deal with them. All the others can be handled at the local or regional level.

Still, a major chemical transportation accident is a scary thing—akin to a hurricane, earthquake, or major oil spill in its potential to cause damage. And, because there are so many kinds of hazardous chemicals, each requiring its own type of special handling and capable of interacting with other chemicals to compound the hazard, chemical disasters are much harder to prepare for than are natural disasters or oil spills.

The first people to become involved in an accident involving hazardous chemicals are usually people from the local community—either the police or the fire department. Of all the groups that eventually may get involved, these are the people least likely to know how to handle such an emergency. And, because there are so many local police and fire departments, the task of better preparing these people to handle chemical emergencies is awesome.

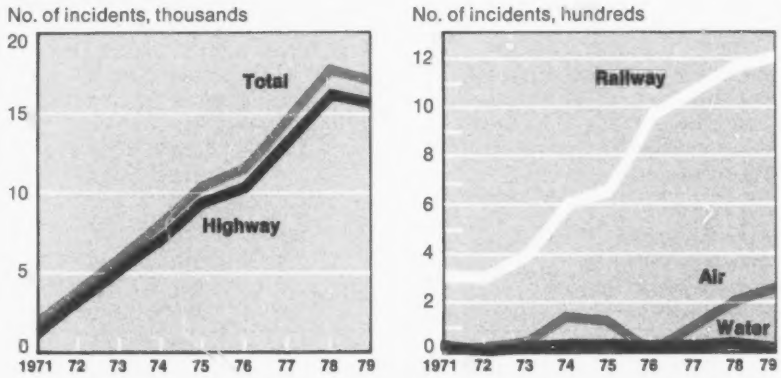
Communities usually handle chemical disasters less well than they do natural disasters, says Enrico L. Quarantelli, director of Ohio State University's Disaster Research Center, which has been studying community response to chemical disasters for the past three years. There are two main reasons for this. Chemical disasters are more complex than natural disasters in that more different kinds of things can go wrong. But communities also are less well prepared to tackle a chemical disaster effectively. They often have not worked out answers to questions like who will be in charge of various aspects of disaster relief, or what kinds of help and information will be needed and where can it be found.

"Field observations . . . frequently document confusion, uncertainty, lack of coordination, and general inefficiency in the mobilization of resources when confronted with a sudden chemical threat," Quarantelli says. "The picture one frequently gets is similar, although on a smaller scale, to that depicted by the Presidential Commission on the Three Mile Island nuclear accident; that is, the technological safeguard proved relatively adequate, but the human error and organizational flaws were such as to almost turn a rather routine accident into an incredibly disastrous catastrophe. Many small-scale, dangerous chemical incidents are frequently transformed into potentially larger and more serious events by inept efforts at initial response."

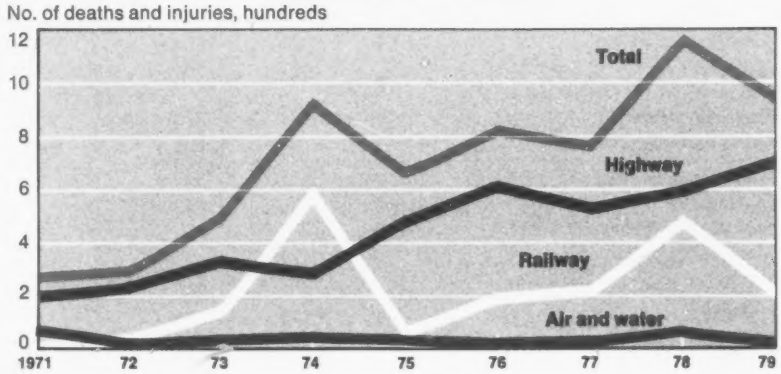
Help and information are available to communities both in planning for chemical disasters and in handling them when they occur. The oldest and probably most widely used source of help is CHEMTREC, an acronym for CMA's Chemical Transportation Emergency Center. Begun in 1971, CHEMTREC has a 24-hour, information hot-line that can provide data on the hazardous properties of about 18,000 chemicals and chemical classes for fire fighters and other on-the-scene emergency personnel. Equally important, CHEMTREC can quickly locate and notify the chemical shipper who can provide expert assistance, either over the telephone or on the scene if it is needed.

CHEMTREC provides only information; it will not tell on-scene personnel how to fight a particular emergency, a policy often faulted by local fire fighters who are trying to cope with a completely unfamiliar emergency and do not know where else to turn for help. However, Zercher defends the policy: "We will not put judgment on the telephone," he says. "We will tell on-scene personnel the properties of the chemicals involved if they know what the chemicals are, we will help them identify the chemicals if they don't

Transportation incidents involving hazardous materials are on the increase . . .

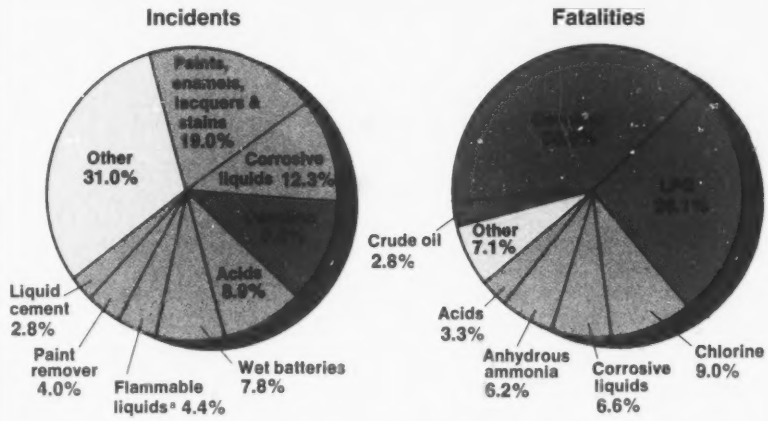


. . . as are the resulting deaths and injuries



Source: Department of Transportation

Though hazardous materials involved in most transportation incidents are nonfuel chemicals, fuels cause most deaths



a Not otherwise specified. **Note:** Data are for reported incidents, 1971–78. **Source:** Department of Transportation

know, and we will immediately put them in touch with the company whose chemicals are involved and let the company's expertise come into it."

CHEMTREC's strengths, as Zercher sees them, lie in its extensive files and in the cooperation of participating companies. It is probably at its most impressive, both Zercher and users agree, in passing information about an incident to the company whose product is involved. It may have the most extensive files available on who owns or leases specific tank cars and, thus, whose product is likely to be in them, for example. And the CHEMTREC coordinator knows who within a company to call in an emergency and how to reach that person at any time. It usually takes CHEMTREC less than 20 minutes to track down trained personnel of the chemical manufacturer and relay information to them about an accident.

Except for making its hot-line number as widely known as possible, CHEMTREC concentrates its planning and training efforts on helping chemical companies become better prepared to assist in transportation emergencies, Zercher says. Since 1978 it has sponsored, along with CMA, 14 workshops for chemical industry employees aimed at improving emergency responsiveness within the companies. About 3000 people have attended the workshops so far, Zercher says, and demand continues to grow—so much so that CMA now is trying to arrange for the workshops to become part of the regularly offered program of some university.

Another problem that CHEMTREC is trying to tackle is that of communication to an accident site. Often accidents occur in areas where there are few telephones, and these can quickly be tied up. Also, in an

Certain chemicals are most frequently involved in transportation incidents

	All modes			Highway			Railway		
Commodity	Deaths	Injuries	Incidents	Deaths	Injuries	Incidents	Deaths	Injuries	Incidents
Paints, enamel, lacquer, and stains	0	28	13,304	0	26	13,075	0	0	57
Corrosive liquids	12	306	7,959	10	263	7,660	2	35	235
Wet batteries	0	23	5,429	0	20	5,334	0	0	29
Flammable liquid[a]	5	211	3,076	5	188	2,763	0	19	224
Paint remover	0	60	2,828	0	59	2,781	0	1	17
Sulfuric acid	2	422	2,218	2	212	1,555	0	210	639
Hydrochloric acid	0	104	1,760	0	76	1,502	0	28	237
Electrolyte battery fluid	0	5	1,310	0	5	1,273	0	0	17
Plastic and resin solutions	0	12	1,206	0	11	1,138	0	0	30
Flammable or poisonous insecticides	0	28	894	0	25	876	0	3	13
Ink	1	0	829	1	0	819	0	0	3
Alcohol[a]	0	13	760	0	8	626	0	4	92
Phosphoric acid	0	32	671	0	11	278	0	21	384
Sodium hydroxide	2	178	635	2	120	451	0	54	173
Acids[a]	1	79	573	1	35	537	0	44	25
Anhydrous ammonia	13	404	470	12	265	129	1	139	336
Nitric acid	4	82	437	1	76	395	0	2	31
Solvents[a]	0	4	374	0	4	349	0	0	13
Corrosive solids[a]	0	56	370	0	28	350	0	0	15
Compressed gases[a]	2	62	512	2	61	465	0	1	28
Radioactive materials	0	2	377	0	0	262	0	0	7
Methanol	0	10	350	0	7	236	0	3	106
Rust preventers and removers	0	1	266	0	1	265	0	0	0
Acetone	0	4	219	0	0	171	0	3	38
Xylene	1	7	216	1	3	178	0	0	29
Subtotal	**43**	**2133**	**47,043**	**37**	**1504**	**43,468**	**3**	**567**	**2778**
All other hazardous materials	168	3180	22,988	128	1740	19,790	39	1264	2671
TOTAL	**211**	**5313**	**70,031**	**165**	**3244**	**63,258**	**42**	**1831**	**5449**

a Not otherwise specified. **Note:** Data are for reported incidents, 1971–78. **Source:** Department of Transportation

Mississauga: a disaster that became a miracle

The train derailment at Mississauga is a chemical disaster that was handled about as perfectly as people know how to handle them. Few emergency planners in other areas can say with confidence that they could do as well should such a disaster strike. But they can say that it is possible and feel some measure of satisfaction in knowing how much planning, management, and cooperation can do to mitigate this type of disaster.

It began just before midnight on Saturday, Nov. 10, 1979, when a wheel bearing on a freight car of a Canadian Pacific train overheated. The car was equipped with old-style friction bearings, rather than the roller bearings used on newer cars. Inadequate lubrication allowed friction between the moving axle and the car above it to build up until the stub of the axle broke off.

A grade crossing on the outskirts of Mississauga—Canada's ninth largest city situated about 20 miles from Toronto—knocked off the axle. The car continued to be pulled along the tracks for several miles until another grade crossing knocked the car's dangling undersection off the tracks. It was the 33rd car in a 106-car train, and when it derailed it pulled off 23 cars behind it.

The derailed cars smashed into each other, igniting several cars containing propane and puncturing tankers containing styrene and toluene. Within a minute flammable liquids and vapors ignited in a massive fire that rose nearly a mile in the air and could be seen for more than 60 miles.

The fire was fed by six chemicals—11 tank cars of propane, four of caustic soda, three of styrene, three of toluene, two of glass-fiber insulation, and one of chlorine gas. Of the six, propane, styrene, and toluene are combustible. Chlorine is not combustible in air, but most combustible materials will burn in it, as they will in oxygen. Caustic soda is not combustible, but in contact with moisture it can generate enough heat to ignite combustible materials.

The first steps to combat the emergency were taken almost at once. A trainman quickly disconnected the 32nd car so that the engineer could pull the front portion of the train out of danger. The police and fire departments were notified. Roadblocks were set up and hoses connected within minutes of the crash.

The first BLEVE—a boiling liquid expanding vapor explosion—occurred at 12:10 AM, blowing up a propane tanker and showering the surrounding area with chunks of metal. It knocked fire fighters to the ground and broke windows half a mile away. Within the next 15 minutes, BLEVE's in two more propane tank cars hurled the cars as far as 700 yards.

Photo by Ron Johnson, Ontario Ministry of the Environment

By this time railway officials had been notified, as well as the city's mayor and the Ontario Ministry of the Environment. A copy of the train's cargo manifest and emergency procedures listing was obtained from the train's engine at the next station. Then the first evaluation meeting of senior officials was held. This group included the police chief, deputy fire chief, chief fire inspector, several railroad officials, two officials from the Ministry of the Environment, and local chemical experts.

The group agreed that the most serious hazard came from the chlorine tank car, which already was leaking chlorine and was located so close to burning propane cars that it might explode at any time. Thus, the police chief decided to evacuate some 3500 residents from the nearby area.

This evacuation, the first of 13 that would take place, began about two hours after the train left the tracks. Later, as the wind shifted and the evacuation area grew, the police and Red Cross set up centers to house and feed the people who had been evacuated. Eventually, even these centers had to be moved.

CHLOREP, the chlorine producers' network of chlorine emergency experts, sent a crew from Dow Chemical's Sarnia plant to help. This group decided it would be impossible to seal off the chlorine tank car until the propane fires were out. Meanwhile, fire fighters had determined that they could not extinguish the propane fires. Instead they would cool the cars with water so that they would burn themselves out without exploding.

Sunday morning the province's Solicitor General was notified. He is the provincial officer in charge of emergency planning. By dawn on Sunday, the decision-making committee that would oversee the rest of the recovery effort was complete.

By Monday, Mississauga was feeling the impact of the incident most severely. About 218,000 people had been evacuated. The Queen Elizabeth Way, Canada's busiest highway, which runs along the central part of Mississauga, was closed because officials were afraid that a propane car would explode during rush hour or a cloud of chlorine might waft over the highway and trap commuters in their cars.

By 10 AM the four propane cars still burning were under control, and a nearby tank car manufacturer was preparing a steel patch to place over the 1-square-yard hole in the chlorine car. Air monitoring showed only a few pockets where chlorine concentrations were high enough to be of hazard to healthy adults, but much of the area showed high enough concentrations to cause discomfort.

Early Tuesday morning the last of the propane tank cars stopped burning, and workmen began to seal the chlorine tanker. Wreckage of other cars blocked access to the chlorine car, so they were able to seal the car only incompletely. Nevertheless, 144,000 people were allowed to return home.

Wednesday workers decided to lift and drain a half-empty propane tanker so they could reach the hole in the chlorine tank car. They gambled, successfully, that the propane car would not explode and further tear open the chlorine car.

Thursday and Friday were spent securing the chlorine tank car. When workers finally got in to look at it, they found a layer of slushy ice from the fire hoses was covering the chlorine that remained in the car, shielding it from the air. About 10 of the original 90 tons of chlorine remained in the car, most of the rest apparently having been sucked up into Sunday morning's fire and vented harmlessly over Lake Ontario. The chlorine still in the tanker was pumped carefully into trucks and carried off. By Friday evening, the roadblocks had been removed and the last of the residents allowed to return home. The last ambulance was dismissed the following Tuesday, and the last fire truck left on Wednesday, 11 days after the accident.

C&EN staff photos

Biglane: coordinator is living, breathing environmental assessment team

accident that involves several different hazardous chemicals, it may be necessary for experts on each of these substances to confer with one another or at least know what the others have advised in order to offer advice themselves.

So CMA is setting up a telephone conference center through which the dispatcher can be in simultaneous contact with on-scene emergency response personnel, representatives of chemical companies, and the Coast Guard's National Response Center, which coordinates federal action on hazardous material spills. The center will begin experimental operation in January, covering at first only a four-state area around Washington, D.C., Zercher explains. If it proves useful, CHEMTREC hopes to expand it to nationwide service in about a year.

CHEMTREC also serves as the communication link between on-scene emergency workers and the roughly half-dozen chemical industry mutual assistance organizations that often provide critical help in fighting chemical disasters. Although each of these organizations operates a bit differently, they have several things in common. Each deals with a particular chemical or class with special transportation hazards, such as chlorine, pesticides, or vinyl chloride. For each organization the concept is the same—that the member company closest to an accident will send a task force to deal with it, regardless of whose product is involved in the spill.

The Chlorine Emergency Plan, CHLOREP, operated by the Chlorine Institute, illustrates how these organizations function. Chlorine presents special risks in transportation accidents because it is a poisonous gas that is often shipped in large quantities under pressure, usually by rail. If a tank car leak is threatened in an accident, there is the possibility of a large discharge of lethal material.

Thus the need for CHLOREP, in which 28 chlorine-producing companies have set up 62 regional emergency response teams throughout the U.S. and Canada. The idea is to get one or more of these teams quickly to the scene of an accident.

Chlorine producers have found that the increased speed of response that this system offers them more than makes up for the potential problem of personnel of one company often dealing with the threatened spill of another company's product, explains Robert Mitchell, director of the Chlorine Institute. When an incident lasts for several days, he points out, the company whose product is involved is expected to take over the cleanup operation as soon as possible.

Twice a year the response teams gather in regional meetings to discuss common problems and share with each other successful strategies. Reaction to the program both among chlorine producers and emergency response personnel is uniformly positive. "I haven't heard anybody even remotely suggesting that we stop," says Mitchell.

For incidents of great magnitude and complexity, it is likely that not everyone involved will agree on the best way to clean them up. It is in incidents of this type that the federal government plays a major role.

The government acts according to a National Contingency Plan that is overseen by the Council on Environmental Quality. The plan is an interagency agreement of 12 federal agencies and branches of state and local governments.

At the moment, federal involvement is limited to those incidents in which a specified amount of oil or one of some 300 hazardous chemicals has been spilled and threatens to contaminate surface waters. In such cases, the carrier or local emergency response officials must notify the Coast Guard's National Response Center that a spill has occurred. Some of the superfund bills now before Congress would expand this authority to cover any threat to the environment.

The National Response Center contacts the on-scene coordinator, the kingpin of the federal response. This person is from either the Coast Guard or the Environmental Protection Agency, depending on the location of the accident. The coordinator determines the nature of the spill and what is being done to clean it up and then

Zercher: CHEMTREC's strengths are in extensive files, cooperation of firms

decides whether a federal representative is needed on-site. For about one report in three, someone will go to the spill to observe firsthand how it is being handled.

The federal coordinator has the authority to countermand anyone else's efforts at the accident site and redirect efforts. The coordinator "is a living, breathing environmental assessment team of state and local representatives," explains EPA's Kenneth E. Biglane, who chairs the National Response Team, the interagency group responsible for the federal portion of the National Contingency Plan.

Usually, local authorities, with the carriers and chemical companies involved, are handling the cleanup properly, and the coordinator only endorses what they are already doing. "Total federal takeover is rare," Biglane says, but it can happen. This happens when the interests of the parties involved conflict, in the coordinator's mind, with necessary protection of the public and the environment. In a train derailment, for instance, the railroad may be so interested in getting its stock moving and the tracks cleared that the coordinator thinks its plans to move derailed cars will increase environmental damage. Judgment is involved here, and it often happens that both the railroad and the federal coordinator have considerable experience with chemical accidents, and each is quite certain he or she knows best how to handle the particular incident.

Biglane illustrates these differences in viewpoint with an incident that is currently under dispute between a rail carrier and EPA. In April 1978, a freight train derailed near Crestview, is northwest Florida. During the accident a tank car was damaged, so

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that chlorine gas leaked slowly from it. The on-scene coordinator decided to move the car to a remote location and blow it up so that the chlorine would be quickly dispersed and people who had been evacuated from their homes would be able to return to them. The car's owner, however, questions whether this property destruction was necessary or even the best way to handle the hazard.

In response to this and similar incidents, the National Response Team set up a task force last September to consider the interaction of on-scene coordinators with operators and owners of transport vehicles. One possible outcome of the task force could be guidelines for on-scene coordinators that spell out the priorities they should consider in railroad accidents.

The federal coordinator is not on the scene just to see that cleanup priorities are properly set, Biglane points out. More important in a major incident, the coordinator can call up federal funds and resources if other resources are inadequate. This happens in catastrophic incidents, but it also can happen in smaller ones. For instance, a chemical cargo might be damaged in an accident and need to be disposed of, but no one involved wants to assume responsibility for this disposal.

In addition to initiating the federal response, the National Response Center also provides information on the hazardous properties of chemicals involved in an incident and how to handle them safely. In many ways this service parallels the role of CHEMTREC, a point that critics charge is unnecessary duplication. It also can confuse emergency response personnel who must choose which service to call or whether they should call both.

Although acknowledging the problem, center director Clow points out that each service has its own advantages. The National Response Center, for example, has information on only 980 chemicals, compared to the 18,000 at CHEMTREC. But for the chemicals it lists (which include those most common in accidents), the center can provide more complete information. It has a computer system that can predict such things as how far and how fast the chemicals can be expected to move and how hazardous they will be to people and the environment at each step in their migration.

The center is less well known among fire and police departments than is CHEMTREC, even though the law requires reporting to it, and CHEMTREC is entirely voluntary. This comes about, Clow says, because

C&EN staff photo

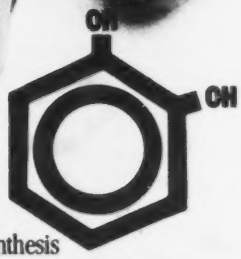
Clow: each service has its advantages

the center worked primarily on oil spill cleanup for the first six years of its existence until EPA issued its list of chemical substances that must be reported to the National Response Center last spring. Before then, the center did provide assistance for chemical incidents, but reporting requirements were less formal than they are now.

The Coast Guard sees its role in the national contingency process as including a strong effort to help communities prepare ahead of time for transportation accidents that might occur. Its hazards assessment computer program, for example, is available for community emergency response planning. The computer can be used to simulate the kinds of incidents that might occur in a community so ways can be developed to handle them.

Revisions to the National Contingency Plan made last spring set as a goal that every community in the U.S. develop its own plan to handle chemical or oil spill emergencies, Clow points out. However, since the plan does not provide the money necessary for local planning, its effect is more to encourage local planning than to make sure that it happens. Such advance planning at the local level is probably the best way to eliminate much of the friction between on-scene coordinators and others in a real incident, according to Clow.

By and large, most people who work closely with the emergency response efforts in the U.S. or who oversee them seem to be satisfied with the philosophy and general approach of the present system. But there are many pesky details that are problems for which solutions seem to take an incredible amount of time to achieve. Indeed, the most common criticism of the system by the National Transportation Safety Board



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and several other critics is how long it takes for earlier suggestions to be implemented.

For example, last September the safety board repeated its recommendation of a year earlier that guidelines be set up to delineate clearly the on-scene command structure in hazardous materials accidents. "Without such a procedure," the board said, "the fire and police units are not able to pass and coordinate information so that each can effectively assess the situation and minimize exposure to unnecessary danger."

Small, but significant problems abound. The Chlorine Institute's Mitchell complains that CHLOREP must be contacted via a telephone number in the 800 exchange, but barges and other users of ship-to-shore telephones cannot make 800 calls. So their requests for assistance have to be relayed, delaying response. Another problem is that self-contained breathing apparatus needed for chlorine emergencies includes compressed gas cylinders. However, compressed gas is itself a hazardous material, and many airlines will not carry it without prior arrangement—something that is not feasible in an emergency.

But the biggest problem, and the one for which easy solutions seem unlikely, is finding the money and time at the community level for extensive planning. Local governments, faced with severe pressures on their budgets, find it very difficult to start any new programs, especially programs to prepare for emergencies that most people still cannot believe would ever happen in their town, according to the Ohio State study.

Other psychological factors also discourage community planning. Planning requires cooperation between different community leaders such as the fire chief, the chief of police, and the civil defense coordinator. Personal rivalries can cause big problems in this.

The Ohio State study concludes that there has been progress toward better community preparedness for handling chemical emergencies. Most communities examined had at least heard of CHEMTREC, and all were to some degree aware that they faced some risk of a chemical transportation incident, although the researchers felt that the actual risk was almost always greater than the community's perception of it.

Increased public awareness of the potential hazards of chemicals in a transportation accident is forcing communities to become better prepared, the study suggests, and federal government programs are encouraging this trend. □

NOTE

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December 1, 1980

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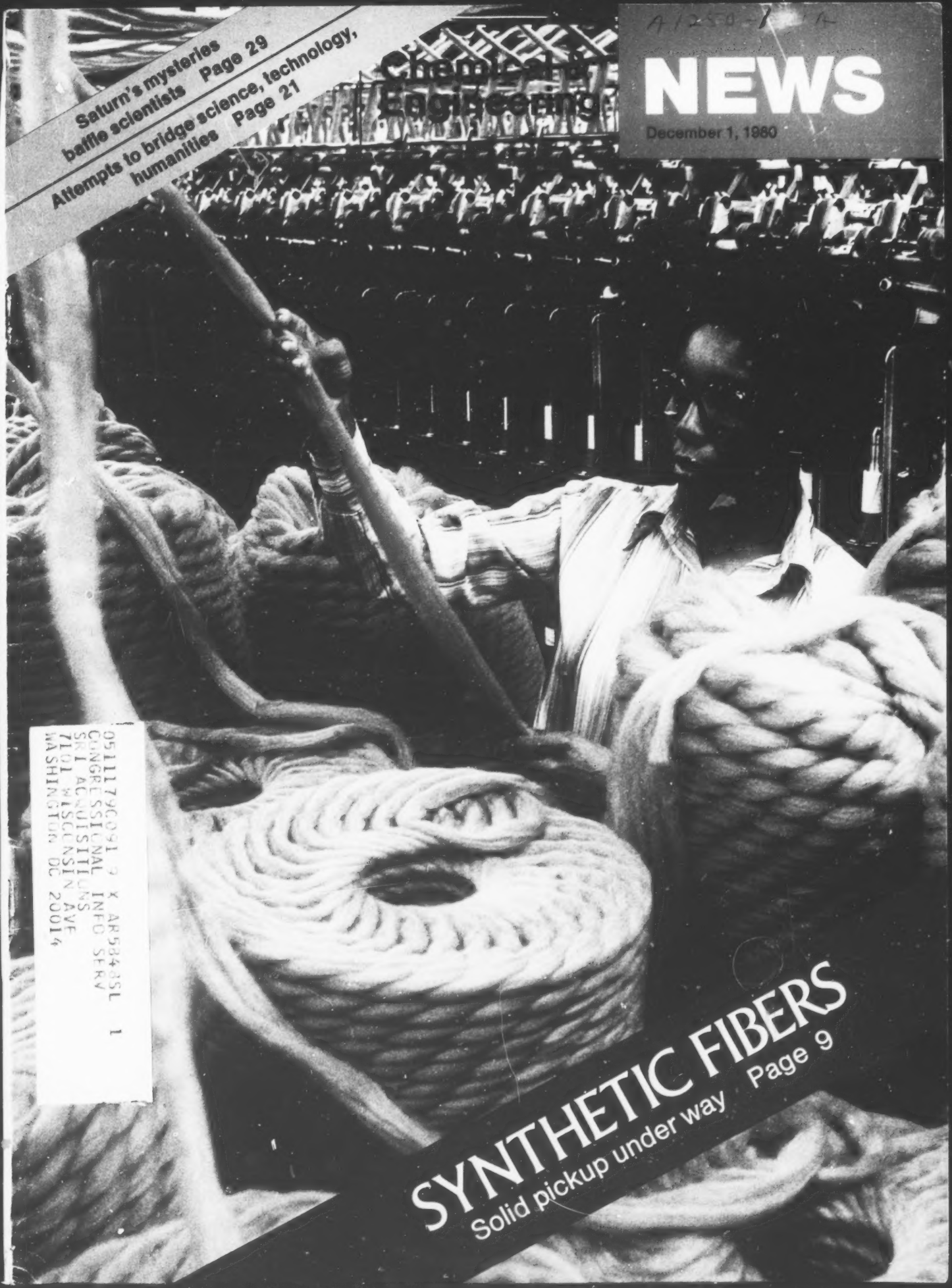
Attempts to bridge science, technology, humanities Page 21



SYNTHETIC FIBERS
Solid pickup under way Page 9

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Chemical & Engineering NEWS

Cover: Worker inspects carpet yarn spun from nylon fiber at Badische's Allendale, S.C., plant

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- ***Superfund bill*** *for cleaning up hazardous substances sites and spills may make it through this Congress: compromise bills have passed both houses and differences could be resolved in conference.* ***Page 6***
- ***Kennecott Corp.'s offer*** *to buy 4.1 million shares of Curtiss-Wright common stock and acquire the remainder in a tax-free exchange for a new stock issue reopens wounds suffered in 1978 proxy fight.* ***Page 6***
- ***National Science Foundation reorganization*** *will boost engineering through its own directorate to emphasize support of engineering research and education, seek resources for engineering disciplines.* ***Page 7***
- ***General Accounting Office report*** *on DOT's handling of hazardous materials transport cites need for improvement in data collection, safety inspection, and coordination of response at accident sites.* ***Page 7***

Business

- ***Following recession,*** *demand for polyester, nylon, and acrylic fibers begins to show signs of upward turn; drop not so severe nor duration so long as experienced during recession of 1974–75.* ***Page 9***
- ***Emphasis on energy conservation*** *enhances market for specialty chemicals and other additives used with coal and fuel oil to reduce smoke and particulate emissions and increase fuel efficiency.* ***Page 13***

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- ***Cross-fertilization*** *of chemistry and chemical engineering curricula was the subject of a two-day conference in St. Louis sponsored by ACS.* ***Page 36***

Synthetic fibers are beginning to recover

Demand slump for polyester, nylon, and acrylic fibers was not so harsh nor did it last so long as that of 1974–75 recession

Producers of synthetic fibers are thanking their lucky stars this year. After dreading a recession that they feared would be as bad as or worse than the one in 1974 and 1975, they were somewhat surprised to find themselves in the shortest recession in some time.

Fibers, a leading economic indicator, began to show signs of a recession, such as declining demand, well before it officially began. But the duration of the slump was not nearly so long as it was five years ago.

Further, the drop in demand this year in no way rivaled the tremendous peak-to-trough drops in 1974–75. After shipments of noncellulosic fibers peaked in October 1979 at 704 million lb, they fell 12% to 631 million lb in June 1980. By contrast, in the previous recession shipments of noncellulosic fibers peaked in May 1974 at 557 million lb and then dropped 52% to 268 million lb in December the same year.

Further, through most of 1974 fibers had enjoyed rather healthy times, and then demand dropped 17% in just one month from November to December. Nothing of this sort happened this time around. The largest month-to-month drop in noncellulosic fiber shipments this year was just 7.6%, occurring between April and May.

One other phenomenon occurred in 1974 that producers hope does not happen now—a loss in longer-term growth rate. In the first part of the decade, synthetic fiber production had been growing at a fairly good clip. Shipments of all noncellulosics were growing at more than 20% per year. Polyester and nylon were following suit. And even acrylic shipments, after growing only 9% in 1971, spurted 19% in 1972 and 21% in 1973. In 1974 polyester shipments dropped 6%, nylon 10%, and acrylic 22%.

Not only did shipments fall dramatically, but it seems that the mid-decade recession also put the brakes on the growth that fibers had been enjoying. In the second half of the decade, annual demand growth for noncellulosics never exceeded 11%, and shipments of the individual fibers grew considerably less than in the first part of the 1970's.

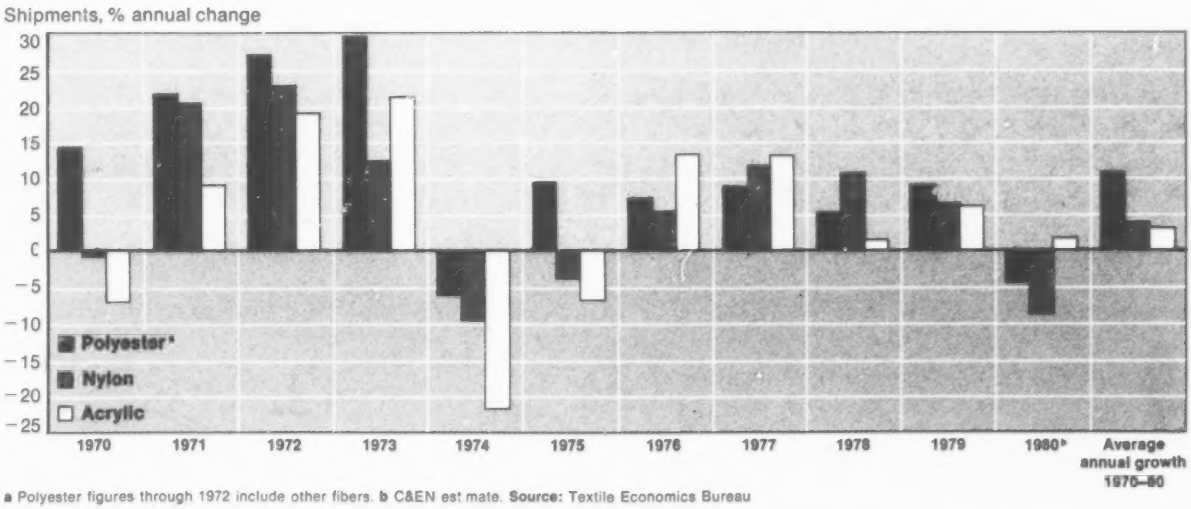
Pricing changes during the late 1970's have not been able to keep up with raw material costs in many cases, because production capacity has grown faster than demand. Though producers always were aware that they were in a cyclical industry, the mid-70's recession with its precipitous drop in demand brought this fact home with a vengeance. The result has been that fibers marketing is looked on in different ways than it once was.

Many of the producers now look on fibers markets as durable goods, even though they are not classed that way by government surveys. The reasons for this changed perspective are twofold. The first is that many of the fibers' end markets are in durable goods, such as automobiles and housing. The second is that fiber producers are taking a different view even of such end-use markets as apparel. When money gets tight, they say, purchases of carpets, tires, and even clothing can be deferred. Thus, these markets must be treated as durable goods markets just as any deferrable big-ticket purchase market.

For a more detailed outlook for polyester, nylon, and acrylic fibers, see the following pages.

William Storck, New York

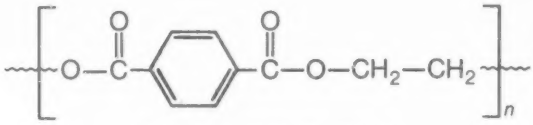
This year's recession was not so severe for fibers as that of 1974–75



a Polyester figures through 1972 include other fibers. b C&EN est mate. **Source:** Textile Economics Bureau

Key Polymers

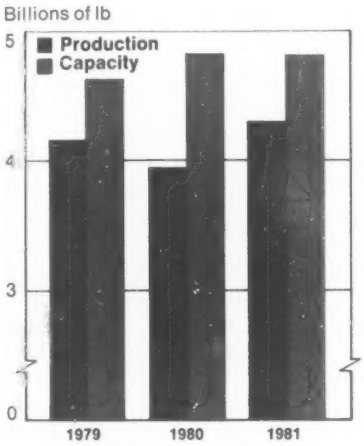
Polyester



Poly(terephthalic acid)

- ***Demand increasing***
- ***Capacity down slightly***
- ***Prices improving***

PRODUCTION/CAPACITY



HOW MADE

Reaction of ethylene glycol with dimethyl terephthalic acid or with terephthalic acid to produce resin that is spun into fiber

MAJOR END USES

Apparel 61%, home furnishings 18%, tire cord 10%

FOREIGN TRADE

Exports—rising to about 650 million lb in 1980, imports—falling to about 13 million lb this year

PRICES

150-denier textured filament, $1.05 to $1.08 per lb; 150-denier feeder filament, 85 cents per lb; staple, 82 cents per lb

COMMERCIAL VALUE

About $3.5 billion for total production, 1980

Polyester, the largest-volume, man-made fiber of the petroleum-based noncellulosics, suffered much less in the recent recession than did its nearest neighbor, nylon. But it was not so lucky as the third largest fiber, acrylic.

Through July, which was the low point for polyester fibers, shipments had fallen 6.8% from year-earlier levels. The demand for the fiber has recovered somewhat since then and shipments through September were 4.9% below what they were in the first nine months of 1979.

However, demand for polyester fiber has not been good across the board. In fact, demand for all of the major categories of polyester has fallen, except for the largest volume type, polyester staple.

Industrial polyester filament (that having denier coarser than 700) has been the big loser in the recession. Use of this filament, largely in tires, declined 28% in the first nine months of 1980 from the like period last year. The next largest decrease was by polyester textile filament, demand for which dropped 10.8% in the first nine months of the year. Of the filaments, low-denier polyester performed the best, with only an 0.8% drop for the January-through-September period.

Only polyester staple (chopped form) has performed better in 1980 than in 1979. Shipments of polyester staple through September rose slightly (0.8%) from the first nine months of 1979. Although this doesn't seem to be much of an increase, the volume of polyester staple is such that it alleviates considerably the drop in total shipments. Polyester staple shipments outweigh filament shipments almost 1.7 to 1.

Polyester staple goes primarily to two markets, carpet and apparel. Although new home construction and thus the need for new carpet was lower than it was last year, the replacement market for polyester carpet held up fairly well, producers say.

Producers' inventories of polyester fibers have been held pretty well in check. Although stocks on hand were swelling during the first half of the year, producers put the brakes on rather quickly. June of this year saw a big sell-off of inventories, and at the end of June stocks were almost 6% less than they had been at the end of May. By the end of September inventories at the producers' level had fallen 39% from what they had been at the end of May.

According to producers, their own customers during the same period were using up their inventories. The combined effect of these two depletions of stocks sent operating rates plummeting at fiber plants, but producers view this as a good thing in the long run.

It was good, they say, if for no other reason than it forced some marginal production units to close, thus reducing polyester production capacity. All told, about 200 million lb of capacity has been shut down this year. Though some of this may be restarted when the economy picks up, the majority, such as that at Texfi and Fiber Industries, is a permanent shutdown.

The higher operating rates for polyester fiber plants brought on by the shutdowns as well as the lower inventories hanging over the market have improved the pricing structure for polyester. The price of texturized 150-denier polyester filament has improved to $1.05 to $1.08 per lb in September from just 95 cents per lb at the beginning of the year. Polyester feeder filament price also has improved and is now 85 cents per lb. Polyester staple prices have been the weakest of all of the polyester fibers. They currently cost 82 cents per lb, a level where they have languished for some time. However, discounting, which was taking place earlier this year, has virtually been eliminated.

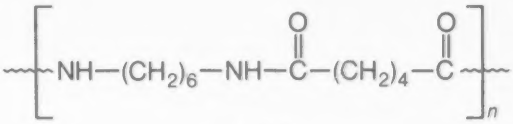
Prices may rise in January, but it's still uncertain. Celanese has announced a 12 cent-per-lb increase for polyester fibers effective the first of the year, but as yet, none of the other producers have said that they would go along with the increase.

If polyester turns around the way producers hope it will, there will be no question about a price increase. Makers of polyester fibers expect that demand next year will be about 8% above what it has been in 1980. If this turnaround does take place to the satisfaction of producers, operating rates will be above 90% for the first time in a long time.

Thus, 1981 looks like a fair year for polyester, with demand 8% above 1980 levels, but only about 3% above the 1979 levels before the recession.

Key Polymers

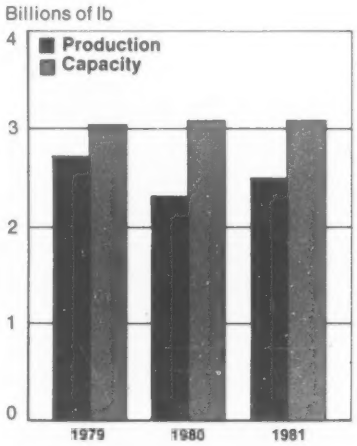
Nylon



Nylon 66

- ***Demand rising***
- ***Capacity rising***
- ***Prices rising***

PRODUCTION/CAPACITY



HOW MADE

Nylon 66—reaction of adipic acid and hexamethylene diamine to form hexamethylene diammonium adipate, nylon 6—polymerization of caprolactam catalyzed by water; both types are then spun

MAJOR END USES

Home furnishings 61%, apparel 18%, tire cord 11%

FOREIGN TRADE

Exports—rising to about 188 million lb in 1980, imports—will increase to about 30 million lb

PRICES

2500-denier bulk continuous filament, $1.25 per lb; carpet staple, 95 cents per lb; 40-denier tricot, $1.90 to $1.95 per lb

COMMERCIAL VALUE

$2.5 billion for total production, 1980

It has not been a good year for nylon fiber. In fact, among the top three noncellulosic fibers, nylon has suffered the most during the recession. More to the point, the nylon recovery may take longer than that for either polyester or acrylic.

Through the first three quarters of 1980, shipments of nylon fiber had dropped almost 15.5% to about 1.74 billion lb from the comparable period of 1979, according to the Textile Economics Bureau.

The big drop in nylon shipments is blamed primarily on the poor construction market during the past year. Shipments of nylon staple (chopped form), which is used mainly in carpets, have dropped 28% through September from the nine-month 1979 level. Even this cumulative drop represents an improvement for the past three months. At midyear, staple shipments were 33% lower year-to-year.

Oddly enough, nylon carpet filament did not follow the deep drop of staple. Carpet filament through September fell only 6% from the nine-month 1979 level.

The best performance in 1980 among nylon types has been in low-denier industrial nylon. Demand for this low-volume product fell only 2.8% through September from last year's levels.

Industrial filament in higher deniers, 700 and coarser, has followed the market for large tires, its major use. Shipments of the coarser industrial filaments have dropped 11% through September from levels during the same period last year.

Overall, nylon had the largest peak-to-trough drop in the recession of the three major fibers. Nylon fiber shipments hit their highest point at 238 million lb in June 1979. They then fell 34.5% to their lowest point of 156 million lb in June 1980. Even so, this was better than in the recession of 1974–75 when the peak-to-trough drop for nylon was 60%.

One of the reasons for the smaller nylon slump this time around, as in the other fibers, was producers' inventory control. Producers quickly adjusted to keep inventories equal to or less than one month's shipments, considered ideal.

Specifically, nylon inventories at the end of January were just about equal to January shipments. By June, however, inventories swelled to a little more than one and a half of June's shipments, their highest ratio of the year. This was quickly cut back by producers to a corresponding figure of just 70% of that month's shipments. In fact, September inventories at nearly 163 million lb were 26% below January and 36% below June.

The fast inventory sell-off in the third quarter benefited nylon pricing. Prices in many nylon fibers started out the year at a relatively strong level and slumped considerably through the summer, when demand was at its lowest and inventories at their highest. Since summer, however, prices have been moving up considerably.

For instance, carpet staple began the year at 82 to 83 cents a lb, then dropped to under 70 cents a lb in July. By October, prices had rebounded to 75 to 80 cents a lb, and on Dec. 1 they are slated to rise to 95 cents a lb.

The only remaining weak spot for pricing is in textile filament nylon. Prices for 40-denier textile filament have stayed about the same all year at about $1.90 per lb.

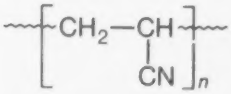
For 1981, producers are optimistic, although they do not expect nylon shipments to return to 1979 levels until 1982. Producers say that nylon demand will increase about 8 to 9% in 1981. Much of this growth will be in the home furnishings area, particularly carpet nylon. Good growth also is forecast for bulk continuous filament carpet nylon and for carpet staple.

Some of this growth in 1981 will be in a hopefully resurgent home construction industry, and some in the so-called replacement carpet market. Producers also are hopeful that the commercial construction industry will not sag next year. Commercial construction, which did not fall into a hole as did residential construction this year, helped keep the wolf from the door of many nylon producers.

Construction of offices, stores, and other commercial facilities that are big users of nylon carpet, primarily because of its durability, will keep pace with last year, nylon producers hope. However, if interest rates do not back off, even this part of the business could be hurt.

Key Polymers

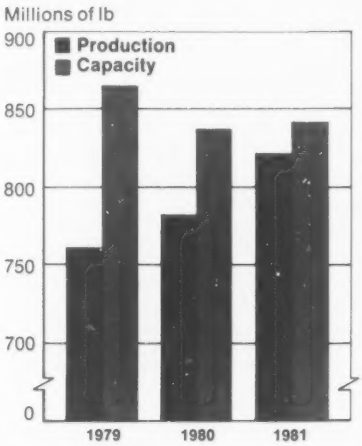
Acrylic



Polyacrylonitrile

- ***Demand up***
- ***Capacity stable***
- ***Prices increasing***

PRODUCTION/CAPACITY



HOW MADE

Polymerization of acrylonitrile, which is made by a catalytic reaction of propylene and ammonia

MAJOR END USES

Apparel 70%, home furnishings 30%

FOREIGN TRADE

Exports—dropping to just over 130 million lb in 1980; imports—stable at about 15 million lb

PRICES

88 to 90 cents per lb for 3-denier staple for apparel

COMMERCIAL VALUE

More than $700 million for total production, 1980

Energy conservation is helping acrylic fiber, which has come through the 1980 recession in enviable shape. Although acrylic long has been regarded as the weak sister of petroleum-based noncellulosic fibers, this year the demand for sweaters and warmer outergarments held up better than for either nylon or polyester.

Shipments of acrylic through September are 1.4% ahead of last year at 584 million lb and probably will finish the year about 1.5 to 1.6% ahead of 1979. At the lowest point of demand for acrylic in July, the cumulative shipment figure for the year was 467 million lb, 3.9% ahead of the first seven months of 1979, according to the Textile Economics Bureau.

Performance would have been even better this year but for one thing. Exports of acrylic fell considerably owing to pressure by Europeans to curtail U.S. imports into the European Economic Community.

Acrylic producers say that U.S. demand for the fiber is about 9% ahead of last year. Hence, if exports had held up, acrylic fibers would be having a banner year.

The result is that, in spite of the recession, acrylic fibers are not growing much less than their average growth rate since 1976, which is 3.8% per year. This year's performance has so buoyed producers that they are forecasting a 10% rise in U.S. demand for apparel next year. This would translate into about a 5% rise in total demand for U.S. acrylic. Even so, some producers still are forecasting long-term growth for acrylic fibers at no more than 1% per year.

In many respects, acrylic fibers had it their way in 1980. Production capacity, which had been relatively stable for many years, dropped about 3% from the first quarter of 1979 to the first quarter of 1980, improving capacity use. Feedstock acrylonitrile availability has been fairly good, and the price stabilized after a first-of-the-year increase. And acrylic fiber inventories never got out of hand. They have consistently stayed below the traditional one month's shipments level throughout the year.

However, a scheduled acrylic price increase in July did not succeed, and prices have remained fairly flat all year. A new price increase of about 10 cents a lb is scheduled for January, which will bring the price of industry standard 3-denier staple to 98 cents to $1.00 per lb.

Imports have hurt acrylic somewhat. Although the balance of trade looks good from the standpoint of raw fiber, with exports outweighing imports about 8.5 to 1, the picture actually is not so rosy. Much acrylic is imported in the form of finished goods, thus driving down U.S. demand for the raw fiber.

The capacity utilization picture has brightened considerably for acrylic fibers, as much from shutting down excess capacity as from a pickup in production. Capacity utilization stood at about 88% in 1979. The shutdown of excess capacity plus a 3% gain in output expected for 1980 will push capacity use to more than 80% this year. If all goes as producers expect, U.S. acrylic industry capacity use probably will exceed 95% in 1981.

This is pushing capacity use to the point where producers will have to start thinking about expanding plants. As yet, no expansions have been announced. For years, the economics of acrylics have not favored expansion. For instance, the price of acrylic in the past two years has increased a total of just 18%, below consumer price inflation. Before 1978, growth of acrylic prices was slower than that.

The one big advantage held by acrylic fibers is that they more resemble wool than do either nylon or polyester. Thus, in spite of a trend to natural fibers, or perhaps because of it, the demand for acrylic will be expanding in the apparel market.

Producers see apparel as the only growth part of the industry for the future. About 30% of acrylic production goes to home furnishings, mainly blankets and carpeting, but producers expect this percentage to decrease, perhaps significantly, in the future.

Thus, producers are pinning their hopes on a previously cyclical market whose problems are further compounded by imports of usually cheaper foreign finished goods. Ordinarily not a good gamble, this strategy works for acrylic because, at the moment, energy conservation and the natural-fiber look are more important.

NOTE

ONLY THE FOLLOWING PAGES OF THIS PUBLICATION

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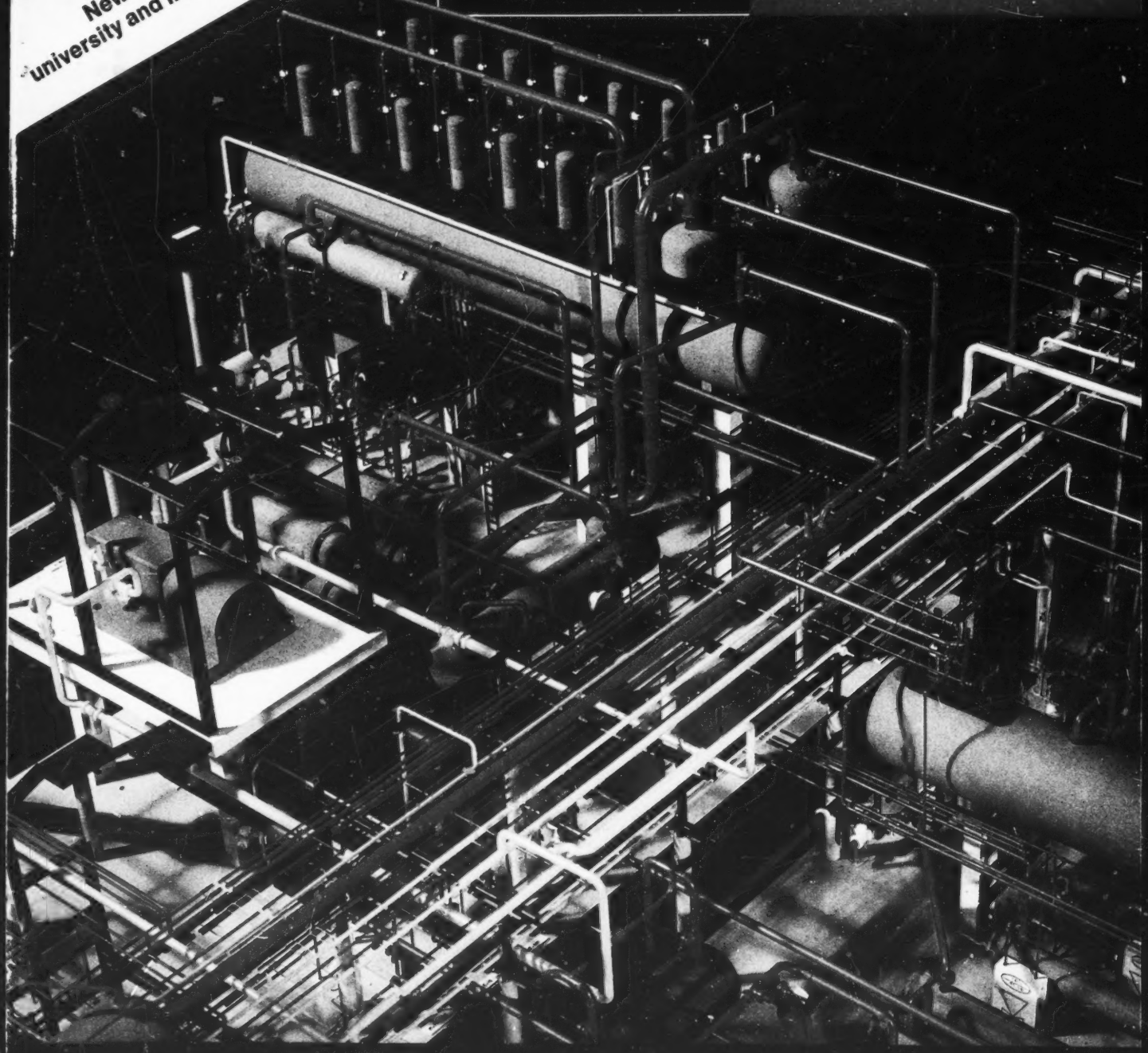
Chemical & Engineering NEWS
December 8, 1980

New and stronger ties to bind university and industrial research Page 38



Chemical capital spending plans for 1981
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Cover: Plant model, one of the early stages of new plant construction. Photo courtesy of Pullman Kellogg

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News of the Week

- ***The U.S. economy will continue to recover*** *but at a slower pace than that since July, NAPM pundits predict.* ***Page 6***
- ***Guidelines for joint research ventures*** *have been issued by the Justice Department's antitrust division.* ***Page 6***
- ***American Cyanamid's earnings*** *for 1980 will be down slightly from 1979.* ***Page 7***
- ***Dow Chemical will boost operations in Japan*** *through a new vinyl chloride plant and a liquid chemicals terminal.* ***Page 7***
- ***Supreme Court rules*** *EPA is not required to consider economics in granting variances under part of the Clean Water Act.* ***Page 8***
- ***Photochemist W. Albert Noyes Jr.,*** *former editor of three ACS journals, is dead at age 82.* ***Page 8***

Business

- ***Capital spending by U.S. chemical firms*** *in 1981 may rise about same as inflation rate following 21% gain in 1980.* ***Page 19***

Government

- ***Basic and applied research fields*** *getting larger share of government R&D funding, NSF studies show.* ***Page 23***

Science

- ***Advances in nitrogen fixation*** *made by agricultural researchers; efforts to expand range of plants bear fruit.* ***Page 29***
- ***Revised NIH guidelines*** *for recombinant DNA research raise clamor for further revision of biosafety committees.* ***Page 30***
- ***Revision of vocational guidance inventory*** *includes information from some 500 male and female chemists.* ***Page 31***

Technology

- ***Technique to accelerate fabrication*** *of glass preforms for glass fibers used in lightwave communications developed by researchers at Bell Telephone Laboratories.* ***Page 34***

Special Report

Industry/university cooperation in research *is becoming more widespread, thanks to a growing recognition by scientists from both camps that they can work together for their mutual benefit.* ***Page 38***

Books

- ***"Environmental Ethics: Choice for Concerned Citizens"*** *purports to formulate ethical principles for using the environment but scientific background is shaky.* ***Page 57***

ACS News

- ***Challenges facing chemistry*** *in the coming years was the focus of conference of top chemical leaders held by ACS.* ***Page 63***
- ***ACS survey of pension plans*** *of chemical employers finds 77% require no financial contributions from employees.* ***Page 64***

Chemical capital spending restrained in 1981

Worldwide capital spending by U.S. chemical firms may rise only 8% in 1981, about same as inflation, following 21% gain in 1980

William F. Fallwell
C&EN, New York

The U.S. basic chemical industry has essentially pressed the "hold" button for investment in new plant and equipment, its largest use of funds after paying ordinary costs and taxes. So has the largest investor group in U.S. chemicals from outside the country, the West German chemical industry.

It isn't hard to see why. Moderately strong investment in 1979 and 1980 pushed up chemical plant capacity at the same time a recession pulled down demand. Hence, although the industry generally sees a healthy new business expansion on the way and a new investment pickup coming eventually, a big boost in plant outlays can wait for now.

For 1981, C&EN's annual survey of the largest U.S. basic chemical companies finds a 8% current-dollar increase due over 1980 in worldwide outlays of capital for new plant and equipment. With inflation of 8 to 10% figured in, spending in 1981 will be about flat.

In 1980, these companies estimate capital spending is up 21% from 1979 after an 18% increase in 1979 from 1978. The 1980 figure is somewhat above companies' original budgets a year ago, which forecast an increase of 9% for the year (C&EN, Dec. 10, 1979, page 14). The increase has been growing all year, with a 16% pace at midyear (C&EN, June 9, page 49). To judge some companies' nine-month statistics, the fourth quarter will turn out to be a strong period.

Even with back-to-back increases of about 20% in 1979 and 1980, capital spending has remained relatively low compared to the industry's basic business volume. Capital spending is running about 10.2% of sales in 1980 after 9.3% in 1979. For 1981, assuming a sales increase of 15%, the corresponding capital spending figure will be 9.6%. All these percentages are on the low end for the capital spending cycle. Highs over the past 20 years have hit 13 to 14%.

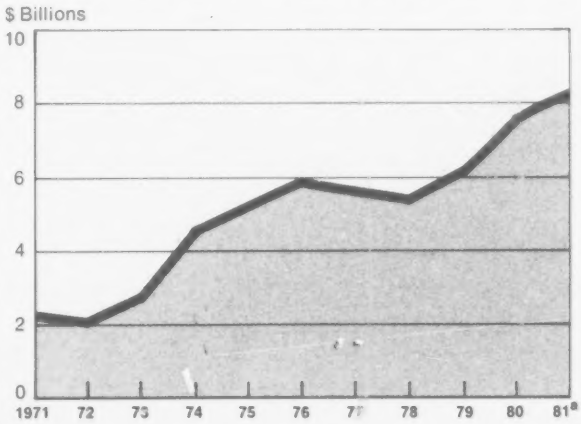
A little nonbudget analysis shows the considerable force for restraint behind companies' initial capital spending plans for 1981. Actual net plant capacity in the most important basic chemicals has risen 6% from 1979 in the U.S., according to C&EN's latest semiannual roundup on the subject (C&EN, Oct. 13, page 9). However, production is headed for a drop in 1980 of 5% or so.

At the worst of the recession in mid-1980, production in the leading basic chemicals was down 9% from a year earlier. As a result, plant capacity use sank to 66% from 81% in mid-1979. Profits fell sharply, 16% year-to-year in the third quarter for basic chemical companies.

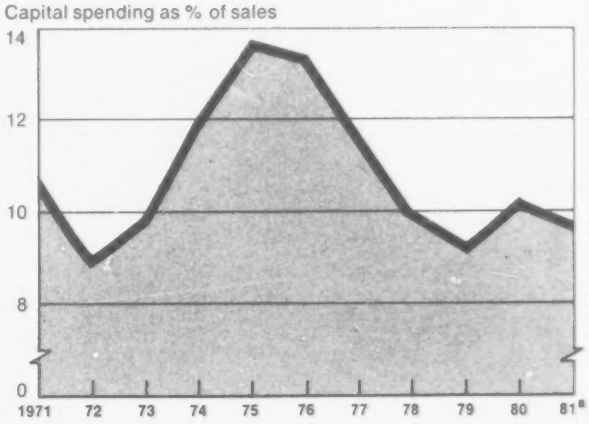
However, companies had to proceed with some big construction projects begun two to three years ago, many of which were ready for expensive startup. For example, Dow Chemical says that it completed $1.8 billion worth of new plants worldwide in 1980, by far the largest total ever for Dow. Although one major unit, an olefins-producing naphtha cracker at Plaquemine, La., did not start up because of market weakness, startup costs at the other locations were high.

Other companies generally face a similar situation, with more than adequate plant capacity for 1981 and even 1982. For example, in basic olefins and aromatics, C&EN's annual forecast puts capacity use in 1981 at 72%, not much of an improvement over 70% in 1980 (C&EN, Nov. 17, page 14). Production of these chemicals has a chance to make it back to 1979 levels in 1981, but capacity for

Chemical capital spending will receive third straight annual boost in 1981...



... but will remain well below its peak as a percentage of chemical sales



a C&EN estimate. **Source:** Combined data from major chemical companies

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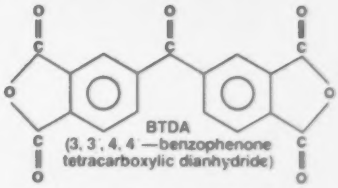

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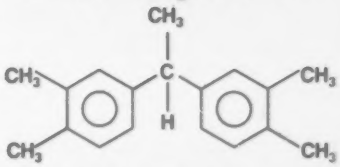

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Several firms hold the line or cut capital spending for 1981

$ Millions	1981 Worldwide	1981 U.S.	1980 Worldwide	1980 U.S.	Worldwide 1980 Planned[a]	Worldwide 1979
Air Products	$ 390	$ 332	$ 365	$ 310	$ 310	$ 246
Akzona	60	60	60	60	60	54
Allied Chemical	675[b]	na	528	na	400	409
American Cyanamid	205	165	190	150	210[b]	235
Celanese	350	na	260	200	260	245
Diamond Shamrock	450	410	400	360	315[b]	257
Dow Chemical	1400	910	1200	780	1200	1268
Du Pont	1300[b]	1100[b]	1200	1020	1000	864
Ethyl Corp.	165	145	135	115	115	123
W. R. Grace	650	563	675	596	500	469
Hercules	220	176	220	165	220	186
Monsanto	800	600	725	544	680	566
Olin	170[b]	160[b]	173	160	140	161
Pennwalt	70	58	63	54	65	67
Rohm & Haas	150	120	95	75	85	68
Stauffer Chemical	200	192	237	227	265[b]	239
Union Carbide	1150	800	1100	737	1000	831
TOTAL FOR 15 FIRMS[c]	$7380	$5791	$6838	$5353	$6165	$5634
ANNUAL CHANGE	8%	8%	21%	24%	9%	18%

a Earliest estimate. b C&EN estimate. c Includes only those companies with figures for all six years. na = not available.

West German firms take breather in spending in U.S.

Capital spending in the U.S. by the three largest West German chemical companies will decline in 1981 after four years of substantial growth.

Planned capital expenditures by American Hoechst, BASF, and Mobay and other Bayer subsidiaries in 1981 will total $495 million, 4.8% less than in 1980. Mobay, the U.S. arm of Bayer, is the only one of the three companies planning an actual reduction in capital spending. It plans on spending less than $200 million next year, compared to $220 million in 1980, according to a company spokesman. The other two companies, American Hoechst and BASF North America (which includes both BASF Wyandotte and Badische Corp.), plan to hold their capital spending at 1980 levels next year.

The decrease for the West German firms in the U.S. next year means that actual construction volume will be well below 1980 levels as inflation compounds the reduction of planned expenditures.

The downward turn is a reversal from recent years' West German investment in the U.S. From 1977 through 1980, the average annual increase for the three companies was 32%.

This is led by Bayer's U.S. subsidiaries with a 45% annual increase. In 1977 the company spent only $72 million in the U.S., but by 1981 this figure had climbed to $220 million. The same is true for BASF, which has increased its spending 22% a year from $91 million in 1977 to $200 million this year. Hoechst is the laggard with just a 15% annual increase between 1977 and 1980.

The planned spending for next year for these companies includes only that spent on plant and equipment. It does not include spending for acquisitions. However, the cost of acquisitions is included in previous years' figures. This may overstate next year's decrease, but if the companies make any acquisitions during 1981, the capital spending figure for that year will increase automatically.

William Storck, New York

U.S. subsidiary (parent)	Capital spending in U.S. ($ millions) 1981[a]	1980	1979	1978	1977	Change 1980–81	Average annual change 1977–80
American Hoechst (Hoechst)	$100	$100	$189	$105	$65	—	15%
BASF North America (BASF)	200	200	136	118	91	—	22
Mobay and other subsidiaries (Bayer)[b]	195	220	150	119	72	−11%	45

a C&EN estimate. b Includes capitalized interest.

Worldwide			Change from previous year	
1978	1977	1976	1981	1980
$ 200	$ 143	$ 162	7%	48%
42	35	38	0	11
502	465	352	28[b]	29
251	235	232	8	−19
248	243	223	35	6
319	389	334	13	56
1075	1163	1200	17	−5
714	704	876	8[b]	39
96	89	88	22	10
285	275	233	−4	44
116	127	150	0	18
480	607	647	10	30
163	208	166	−2[b]	7
62	46	40	11	−6
66	79	110	58	40
201	193	199	−16	−1
688	805	965	−5	32
$4758	$5098	$5440		
−7%	−6%	9%		

them has jumped 17% in the meantime.

Although companies have detailed plans for their next big plant additions, they probably will go slow on spending authorized money in 1981. This is hinted strongly in quarterly surveys by the Conference Board, a business research group in New York City. The Conference Board has found a sizable buildup in unspent backlogs in the chemical industry over the past two years. This has led to a plateau and then a cut in new spending authorizations in 1980.

Two facets of the industry's capital outlays in 1981 and beyond may start to pick up despite the overall caution. One is spending outside the U.S., where relative spending as a part of total capital budgets has receded in recent years to less than 25% because of a decided investment swing toward the U.S. However, management at many companies says that the foreign percentage will gain in the 1980's, especially because of a flow of capital toward hydrocarbon sources in western Canada, Mexico, the North Sea, and the Middle East.

The second rising area is actual new-capacity spending as a percentage of the total capital budget. Dow comments that its part of the budget for new sales capacity will be rising from the recent low point of less than 40%. Even so, more than half of Dow's capital spending still goes for improvements, notably energy savings, in older plants. □

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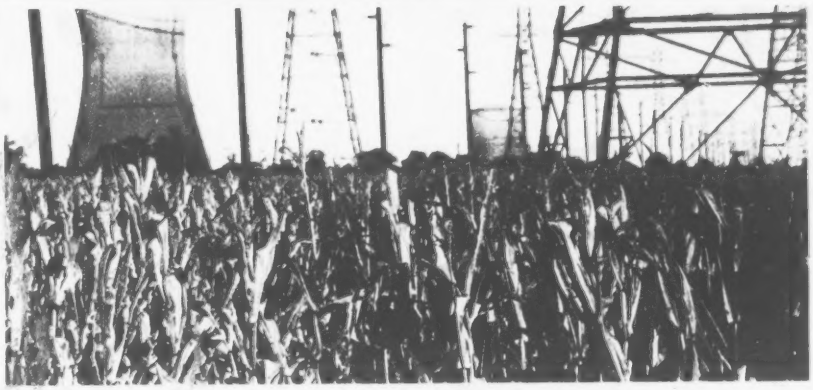

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Research getting bigger slice of R&D pie

NSF study of patterns in government R&D funding in the 1970's shows increase in percentage of funds going to basic and applied research

A National Science Foundation study of patterns in government research and development funding over the past decade shows that defense is taking a smaller slice of the R&D pie, and that energy, biomedical research, and basic research fields have been big winners in recent years.

The study is embodied in a report titled "Federal Funds for Research & Development, Fiscal Years 1978, 1979, 1980, volume xxviii." It is the latest in a series of surveys of science resources published by NSF. However, it does more than just look at three years, it offers a perspective on federal R&D spending for the entire past 10 years.

The 1970's began on a downward path, the report states, with basic R&D funding in a mild slide. Applied research funding was rising, but slowly. As the decade began, R&D funding constituted about 8% of the federal budget. This percentage fell to only 5.7% by 1976, but has managed to hold fairly constant since then and even rise slightly last year.

The four biggest R&D spenders are the Defense Department, Energy Department, National Aeronautics & Space Administration, and Department of Health & Human Services. These handle almost half of all R&D appropriations each year. Most of their funds are for development work, however, and over the past 10 years, development obligations have not increased much. Research, both basic and applied, has increased steadily, if slowly, and the result is that the budgets of these large R&D users have not grown so fast as agencies doing mostly research.

NSF, the Environmental Protection Agency, and the National Institutes of Health, all heavy research funders, made bigger percentage gains in the past few years than DOD, NASA, or DOE. Much of this comes from the push, beginning in 1974, to solve the nation's health and energy problems. President Carter's support for basic research also has led to significant increases.

Aside from describing which federal agencies get how much, the NSF report lists R&D obligations according to their intended purpose. The study points out that federal R&D serves to support national goals or objectives, and that these can cross departmental boundaries. National defense, for instance, is the primary job of the Defense Department, but quite a bit of defense-related atomic energy research is performed under the auspices of DOE.

Energy development is another national goal supported by federal R&D. And, although DOE provides most of the funds, there is considerable energy research done by the Nuclear Regulatory Commission. Other areas supported by the federal government are space science and technology under NASA, where funding levels have been falling slowly since the end of the Apollo moon program; and health research, supported mostly by NIH and the Alcohol, Drug Abuse & Mental Health Administration.

The result of trying to meet national needs through research invariably has an impact on specific sciences. And, although support for research grew 9.2% during the 1970's, some areas prospered, while others did not. Life sciences research, buoyed by the biomedical push in the mid-1970's, averaged more than 11% growth annually; mathematics and computer sciences and environmental sciences each had annual growth rates of more than 10%. Engineering floundered with the lowest growth rate of all, about 6% annually.

Physical sciences also grew slowly. This area comprises chemistry, physics, and astronomy. Physics gets the largest share of funding, more than 50% of the total, and funding for astronomy, the smallest of the three, has been increasing. Chemistry support has grown more slowly than has overall federal research, but substantial increases, as much as 12%, are planned for 1980.

The NSF survey makes no conclusions about R&D funding, nor was it intended to. But there is a pattern visible over the past decade. It appears that the Republican Administration in the early 1970's did not wish to strengthen commitments to research, and funding suffered. Beginning in 1976, more support for R&D surfaced, and since that time, R&D funding has done fairly well, though still often losing to inflation. The Carter commitment to basic research has served the science establishment well, particularly in biomedical and basic research. Now, with a new Administration, one that is admittedly committed to increased defense research, the gains of the past five years by other areas of R&D are likely to suffer. □

R&D funding by budget function slowed in 1980

$ Millions	1971	1978	Annual change 1971-78	1979[a]	Change 1978-79	1980[a]	Change 1979-80
National defense	$ 8,110	$12,899	6.9%	$14,284	10.7%	$15,117	5.8%
Space research and technology	3,048	3,481	1.9	3,944	13.3	4,051	2.7
Health	1,288	2,968	12.7	3,387	14.1	3,444	1.7
Energy	566	3,134	28.0	3,485	11.2	3,429	−1.6
General science	513	1,050	10.8	1,128	7.4	1,248	10.6
Natural resources and environment	418	898	11.5	994	10.7	1,054	6.0
Transportation	728	768	0.8	823	7.1	863	4.9
Agriculture	259	501	8.6	555	10.7	559	0.7
Education, training, employment, and social services	215	345	7.0	347	0.1	352	1.4
Other	412	466	—	528	13.3	550	4.2
TOTAL	$15,557	$26,510	7.9%	$29,475	11.2%	$30,667	4.0%

a Estimate. Source: National Science Foundation

Forging new and stronger links between university and industrial scientists

David M. Kiefer
C&EN, Washington

Item: U.S. university campuses are a vast reservoir of fundamental science. Nearly 60% (almost $5 billion this year) of the funds the U.S. funnels into basic research of all types winds up in academic laboratories and affiliated research institutes. For basic research in chemistry, the universities' share is a more modest 30%, but still a significant $200 million effort.

Item: Pressed by public demands for a quick fix for such social and economic problems as pollution and energy shortages and beset by stiffening technological competition from abroad, industrial scientists express growing concern about U.S. industry losing its long-vaunted innovative edge. Concern about lagging productivity and dwindling innovation is widespread in industry.

Item: University scientists long have been accustomed to look to the federal government as their principal benefactor. Two thirds of all research and development done in universities and colleges is bankrolled by federal agencies. Nearly 80% of academic R&D in chemistry is government supported. But budgetary constraints have slowed the flow of federal funds at a time when rampant inflation has sent the cost of doing research spiraling upward. The consequence, more and more academic researchers lament, will be an eventual drying up of the reservoir of basic knowledge.

Item: In recent years, industry has been more generous than the government in raising its R&D budgets. During the 1970's, outlays for both the chemical industry and all U.S. industry were rising at a 10%-a-year clip—or 3% a year if you factor out inflation. Government support, on the other hand, has shown only a 7% annual increase—which means it has been barely holding its own against price increases.

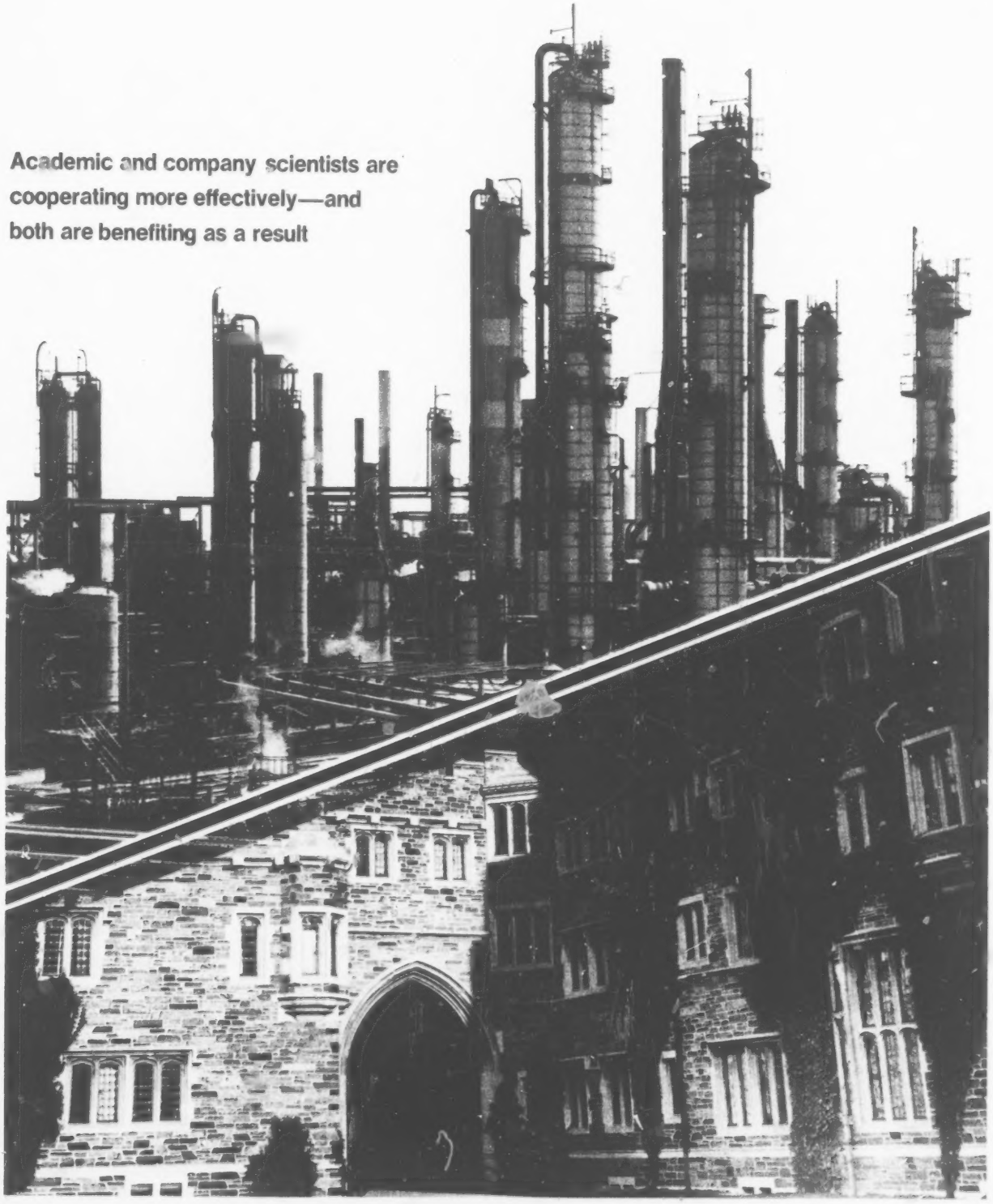
Given these trends, it is no surprise that in the past few years an increasing number of the movers and shakers of the U.S. research community, both in industry and academia—and in government agencies, as well—have concluded that a warmer partnership between U.S. corporations and U.S. universities would have great mutual benefits. Industry could then tap more effectively the academic reservoir of basic scientific knowledge. And schools of science and engineering would have a new (and perhaps more compatible) benefactor to tap for funds. "It's an idea," says Alfred E. Brown, director of scientific affairs at Celanese, "whose time has come."

It's an idea, too, that has been discussed increasingly whenever the makers of science policy have gotten together recently. Just this fall, for example, the subject was on the agenda of the annual meetings of the National Academy of Engineering and the Industrial Research Institute. It was the focus of the second annual conference on cooperative advances in chemical science and technology at Lehigh University last September. The National Commission on Research, which disbanded at midyear after a two-year study of key issues affecting the health of research and innovation in the U.S., issued a report last summer recommending improved cooperative research relationships between industry and the universities. A similar analysis on university/industry cooperation and its relationship to innovation was released by the Center for Science & Technology Policy of New York University in June. Such cooperation also is being studied by the General Accounting Office.

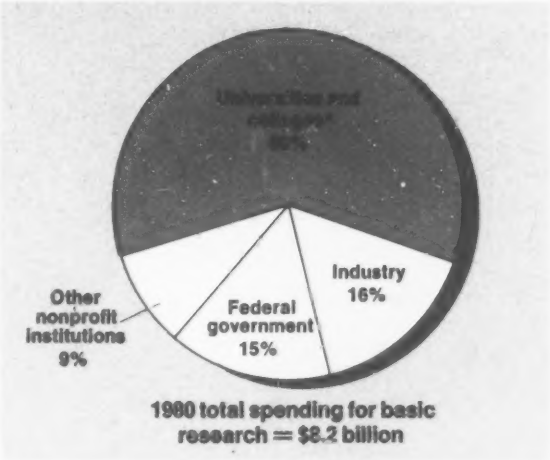
It is clear, from this discussion, that the idea has many strong advocates. Equally clear, however, is the wide disagreement on how best to forge stronger links between academic and industrial research. The issue obviously poses many unresolved dilemmas. Is cooperative research a threat to academic freedom? How do you overcome the inherent conflict between industry's need to safeguard proprietary information and professors' desires to communicate with their academic colleagues? Who should profit from the results? How are goals set? Can the academic lamb really lie down safely with the industrial lion?

On the other hand, industry/university collaboration is not a radically new idea. Companies and the academic community long have recognized that they have many mutual research interests. Industry relies on the universities for the scientists and engineers who staff its

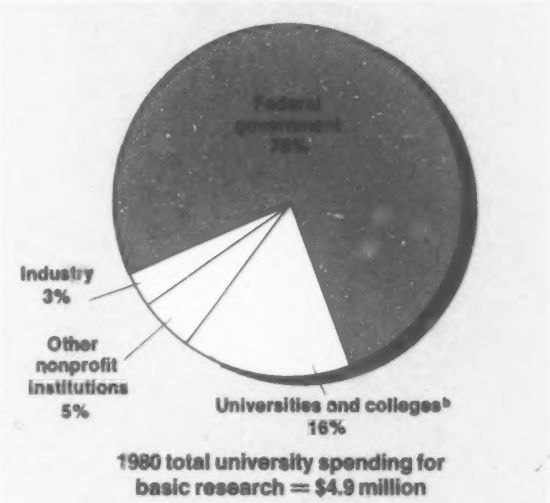
Academic and company scientists are cooperating more effectively—and both are benefiting as a result



Majority of basic research is done in the universities...



... and they get most of their money from federal agencies



a Includes federal R&D centers administered by universities. b Includes state and local government funds. Source: National Science Foundation

R&D facilities, just as the universities look to industry to absorb a large share of their graduates. There is a considerable flow of both ideas and people between companies and campuses. Many industrial firms are accustomed to turn to the academic world as a fertile source of expert advice, and professors find consulting fees a welcome extension of their regular salaries. Less frequently, professors spend a summer or a sabbatical year working in industrial labs, while industrial scientists or engineers teach as adjunct professors on university faculties. Continuing education programs, short seminars, cooperative study programs, and the like all have helped in the transfer of knowledge and experience between schools and companies. Industry executives serve on academic advisory committees and boards, while university people provide similar service to industry. Chemistry Nobel Laureate Melvin Calvin of the University of California, Berkeley, for example, has been on Dow Chemical's board of directors since 1964 (and a Dow consultant since 1946). At the same time, companies have long supported university scientists and engineers with contracts, grants, and contributions.

But financial ties, which had been relatively strong before and during World War II, gradually weakened following the war as government spending for research (on defense, nuclear energy, and medicine, for example) ballooned. In the mid-1950's, federal agencies provided about 55% of the funds spent by the universities and colleges on research. Industrial firms accounted for about 8% of the funds. (The balance came from state and local governments, foundations, private voluntary health agencies, and the like.) By the late 1960's, with the U.S. space program in full bloom, the government's share of academic R&D outlays had expanded to more than 70% of the total. Industry's share fell to under 3%.

Now the tide is showing some signs of running the other way, although not very strongly yet, to be sure. This year, according to estimates by the National Science Foundation, the government will fund about two thirds of all academic research and development, whereas industry's share is up slightly to about 3.5%.

That's still quite small, to be sure. This year, industry is expected to supply only $210 million for academic R&D, out of a total spending by the universities and colleges of just over $6 billion. Perhaps more to the point, however, industry spending for R&D overall has been growing at an appreciably faster clip than government support and actually may surpass total government outlays sometime during the next couple of years. In fact, during the past decade industry outlays for R&D have been growing at a rate nearly half again as fast as government spending. Nearly all of what industry spends, of course, supports its own laboratory and pilot plant efforts. But it's clear that at a time when federal budgets for R&D are appearing more and more niggardly, industry looks more and more promising as a source of funds.

But money—or, to be more exact, the lack thereof—is not the only basis for a growing disenchantment on the part of the academic research world with government support. University scientists also complain about increasing paperwork and red tape involved with federal grants and contracts. They may not argue with the basic premise that they must be accountable for the taxpayers' money that they spend. But many are becoming increasingly annoyed by the detail with which they justify their efforts. Accounting for the time and funds they plow into their projects seems an increasingly onerous and unproductive task. Academic researchers also are increasingly concerned about the reluctance, during a period of high inflation rates, of government agencies to bear all the costs for the research that they support, especially such indirect costs as administration, utilities, and library services. The tendency of federal support, when budgets are limited, to focus on short-range projects with a quick payoff and on small projects of short duration also is a cause for aggravation.

Thus there are reasons enough for academic researchers to seek new sources of support and to turn in that search to industry.

More interest from industry

This renewed interest, moreover, is not a one-way street. Industrial researchers' worries that their companies are losing their technological edge in an ever more competitive world has been leading them to look with greater interest on academic research. The universities, after all, perform most of the fundamental research that is the base for industrial innovation. They have come to

recognize, too, that such research often can be undertaken most effectively in a campus setting and that to duplicate the facilities and staffs available in academia at industrial laboratories would be both wasteful and unproductive. They realize, too, that healthy universities are essential, as sources of trained personnel and basic research, to their own well-being, and that industry could promote this health by better collaboration. And they are aware, also, that the investment they would have to make probably would not be all that great in the overall scheme of corporate finance.

There are, of course, several obstacles that have in the past limited the extent of industry/university ties, especially during the past couple of decades. Perhaps foremost among these is the emphasis that industry has placed, in recent years, on short-term R&D goals with clearly attainable payoffs. Disillusioned with the results of unstructured, free-wheeling research once much in vogue, they lost interest in fundamental work. Funds for such research dried up as a result.

Another troubling issue stems from the distinct differences in the research environment between industry and academic labs. University scientists are jealous of their academic freedom. They want to work on projects of their choice and to publish their results freely. In the competitive, profit-motivated world of industry, the results of R&D typically are proprietary secrets of considerable commercial value; public disclosure is anathema. Patent rights are another contentious issue. The years of campus unrest in the late 1960's and early 1970's also weakened industry/academic ties, especially when companies producing defense-related or environmentally suspect products were involved.

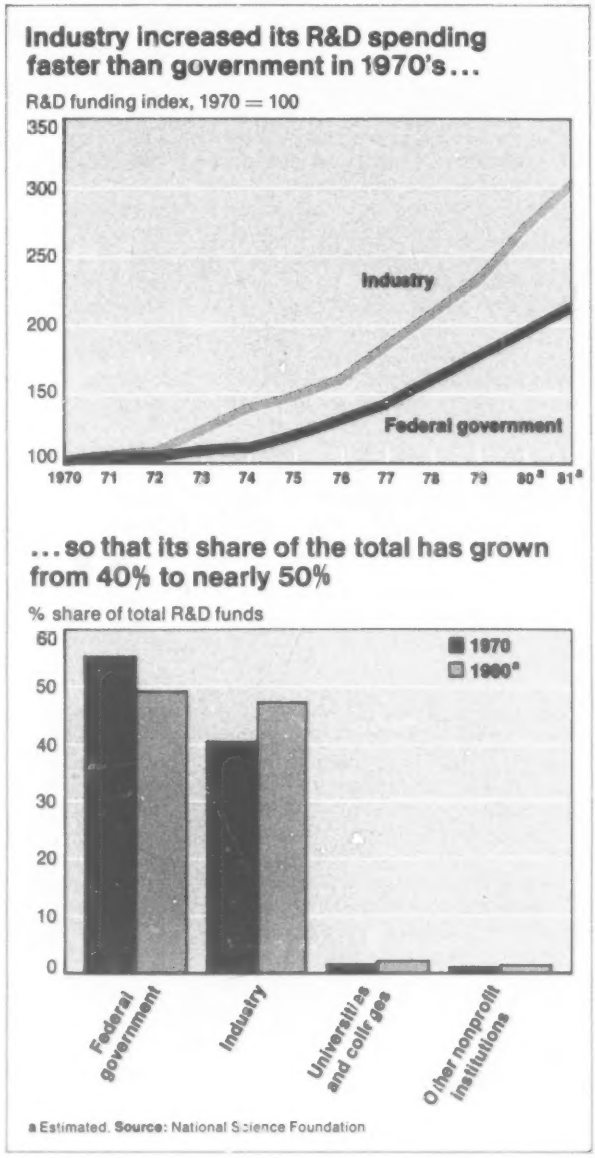
What is new at present, however, is that the obstacles to industry/university collaboration on research seem to be increasingly outweighed by the perceived advantages. Industrial researchers and their academic counterparts are coming to recognize that although their objectives and working conditions may not be identical, they really do have much in common and can work together effectively.

Cases in point:

- Exxon's agreement with Massachusetts Institute of Technology, signed last spring, to fund research on combustion over a period of 10 years.
- Monsanto's even more ambitious joint effort with the school of medicine at Harvard for research on molecular biology. The 12-year agreement, initiated in late 1974, calls for Monsanto to provide up to $25 million to equip a laboratory at Harvard and support research on the biochemistry of malignant tumors over a 12-year period.
- Current efforts in the chemical industry to establish a Chemical Research Council. Membership would be drawn from both the chemical industry and the universities to forge stronger research relationships between industry and academia and provide a conduit by which industry could funnel increased funding for research to university chemistry and chemical engineering departments.

Encouragement from federal agencies

These and other direct university/industry ties are being encouraged by government agencies, notably the National Science Foundation. The two key efforts at NSF are its industry/university cooperative research program and its university/industry cooperative research centers experiment. The first provides grants in partial support of individual research projects involving the collaboration of both academic and industrial researchers. The second helps establish and temporarily support research centers involving the participation of both universities and industrial firms.



The cooperative research center program got under way about seven years ago with NSF funding centers (which then were essentially experimental in concept) at North Carolina State University for research on technology for producing furniture, at MIT on processing polymers, and at Mitre Corp. on technology for New England's electric utilities industry. In the last program, Mitre served as a link between the industry and university researchers. The plan was that support would shift from NSF to the industrial participants over a period of five or so years, on the premise that by that time the program would be self-supporting from industry funds.

Neither the furniture institute nor the Mitre center proved successful. The furniture institute never attracted the strong industry support that had been hoped for. Funds from furniture makers dried up during the recession in the industry in 1975 and 1976. Adequate, sustained leadership never was attained. The institute, too, may have been oriented too much toward a broad in-

Harvard courts a gene-splicing venture, then demurs

Harvard University's recent, somewhat unusual flirtation with venture capitalists trying to set up another new molecular biology-based commercial enterprise has more or less ended. But in the aftermath, the affair may provide some insight into and help to define the boundaries between the academic and industrial communities.

A good deal of confusion has swirled about the public side of Harvard's gene-splicing business plans. How much that confusion contributed to the widespread outcry against the plan is impossible to measure. Nonetheless, outcry, not only from a large contingent of Harvard faculty members but from the wider academic community across the U.S., forced Harvard president Derek C. Bok to drop plans for the university's direct participation in a new enterprise. Just what was all the hullabaloo about?

Harvard has been involved since 1975 in an "active technology transfer program," according to university general counsel Daniel Steiner. Out of that program, which has relied primarily on establishing patent licensing arrangements, grew a plan to get on the molecular biology bandwagon.

"We started discussions with Mark Ptashne last spring," Steiner says. Ptashne, a professor in Harvard's department of biochemistry and molecular biology, has done extensive research in molecular genetics and biochemistry. With a Japanese collaborator, he recently devised methods for producing interferon in bacteria. Those methods have commercial potential. But so do the methods of several other research groups, including groups that are plugged directly into commercial enterprises, such as California-based Genentech and Biogen in Switzerland, that are actively trying to realize that potential.

The discussions with Ptashne were "initiated by Harvard," Steiner says. And it was "Harvard's idea to initiate and form a company." Such a company presumably could have quickly entered the arena to compete with the growing number of other enterprises—including perhaps a dozen small independent ventures in North America and Europe, as well as teams in many of the large pharmaceutical and chemical corporations—now seeking to capitalize on recombinant DNA technologies.

Harvard's plan to form a new company naturally required a source of investment capital. "Harvard spoke with outside venture capitalists to supply capital and expertise to start," Steiner says. But Harvard's plan differs from those of others in that the university was to be a shareholder in the enterprise, although without furnishing any of the initial capital. Nor was the university to furnish space or its name to the company's operations.

Some details of the plan have been publicized in garbled form. But Harvard's Ptashne and Steiner insist that the role proposed for Harvard was to have been strictly limited. "There was to have been no general involvement of other Harvard resources," Ptashne says. The new company was to have been "just like any other company. The only thing different is that Harvard would have owned 10% of the equity."

Harvard's share of the equity and some arrangements for royalties on eventual sales and revenues were offered in exchange for "patents in my lab—only my lab," Ptashne says. This detail of the Harvard plan has received confusing treatment in the press, perhaps because of the way it was presented to the press.

Two things don't appear to fit together. One is Steiner's statement, backing Ptashne's, that the Harvard plan "did not call for broad-scale involvement of the faculty in general." The other consists of statements in a memorandum prepared by Steiner, part of which was excerpted in the *New York Times'* initial account of the plan. In that memorandum, Steiner raises several issues concerning the mixing of academic and commercial endeavors. Particular examples at least hint at broad-scale involvement of Harvard faculty and the potential problems that might arise in such a situation. However hypothetical those examples were intended to be, they have helped to spread confusion as to just who at Harvard was to be included in any actual plan.

This misunderstanding, if that is what it is, has figured importantly in the ensuing barrage of criticism. For example, Stanford University president Donald Kennedy was quick to criticize Harvard's seeming plans and to distinguish them from Stanford's involvement in recombinant DNA-based research as a means for making money. Stanford and also the University of California have applied for patents covering some of the fundamentals of gene-splicing technology. If granted, these patents could prove highly lucrative. Said Kennedy, "Stanford has an obligation to make certain that a proprietary atmosphere does not come to inhibit free scientific inquiry." His sentiments were echoed widely in newspaper editorials across the country.

"It's possible that if the university is a partial owner that some of the problems of the university and industry could be better handled," Steiner says. Thus the Harvard administration entertained the idea that "with a foot in both camps" the university might overcome some of the traditional problems that have plagued would-be cooperative members of the private and educational sectors. This idea "also created a host of problems," Steiner admits. "We have no good answers to all the questions that have been raised."

Harvard's official position is "not to go ahead" now with the proposed venture. But that decision was predicated on what Steiner calls a "serious expression of concern from faculty at Harvard and outside" the university. "We're not passing judgment on the formation of a company—only on Harvard's participation as a shareholder," he says. And that leaves the door open for Ptashne, or for anyone else, to put together just such a company without Harvard's direct involvement, leaving a very fine line between what might be and what might have been.

Might the outcome for Harvard have been different had the issue not drawn so much adverse publicity? It probably would not have gotten so much attention if "we were talking about a new way to make macaroni," Steiner says. But recombinant DNA technology is hot, and nearly every move in the field is being watched closely and often contentiously. Steiner insists that, for Harvard, "the result is just right." And so he rationalizes Harvard's close brush with starting a business as a valuable, "open" discussion.

Harvard's Walter Gilbert is one of the founders of Biogen. Herbert Boyer of the University of California, San Francisco, is a founder of Genentech. Both of these researchers—and of course thousands of others—have patent agreements of one sort or another with their universities. Do these agreements represent some compromise on academic freedoms?

If they do, they're certainly widely accepted and well-established compromises. Ptashne argues that the difference between the established routes for a university's participating in commercialization ventures and Harvard's recently scuttled plans "is really a matter of degree, not principle.

"Maybe it was a bad idea," he says. "It raised so many hostilities." In raising hostilities, the incident has done little so far in answering the question of when academic integrity actually risks being compromised. And it seems as many people these days are wringing their hands about the failure to make such arrangements as they are at the successes.

Jeffrey Fox, Washington

dustry, with many diverse technological problems; it never was able to focus its work on a single coherent technology.

In the New England Energy Development Systems Center, Mitre was to bridge the gap between research conducted at about a dozen universities, most of them in New England, and the needs for new technology by electric utilities also in New England. But the technology brokerage concept never really was pulled off. The utilities' interest in the technology being offered them was low. Lack of adequate funding from industry, again, was a problem.

The MIT polymer center, on the other hand, in the opinion of most observers has been an unqualified success and is now self-supporting. The center was formed in 1973 with mechanical engineering professor Nam Suh as director. Of $150,000 in initial funding, nearly two thirds came from NSF and the balance from three industrial sponsors. Its objective was to provide long-range basic and applied research needs for plastics processors, while at the same time offering research opportunities and financial support for MIT students and faculty. NSF funding expanded moderately during the first three years of operation, then dropped sharply for the next two years, stopping entirely after 1978. All in all, NSF provided $469,000 to the project.

Meanwhile, industrial participants increased steadily to a present total of 12, which Suh believes is about the maximum that the program can accommodate effectively. The participants cut across a broad range of industries that process and fabricate plastics, ranging in size from such giants as General Motors, Eastman Kodak, and Xerox to such relatively small businesses as Rogers Corp., Instrumentation Labs, and Lord Corp.

The center has worked on projects dealing with such matters as impact forming, injection molding, mixing and pumping polymers, glass reinforcement, and laminating and stamping processes. About 15 projects are under study, largely by graduate students, at any time. They are selected by the MIT faculty, although an advisory committee of representatives from the industrial participants provides suggestions. Strong interaction between the industry and MIT people—through periodic review meetings—is an important factor in the program's success. The fact that the MIT polymer center has been in the education mainstream at MIT, with strong participation by both faculty and students in its operation, is another factor that probably has made it more of a success than either the furniture or the Mitre centers, neither of which ever had very much campus visibility.

As Robert M. Colton, who heads NSF's university-industry cooperative research centers program, puts it, "Leadership is the most important factor in success. You need a university person, preferably well-respected, mature, with industrial experience, and academic tenure, to take charge. But the university itself also must really want the institute, as well, and be willing to commit space and some money and to reward the professors who are involved. There must be no doubt about the academic quality of the research. Finally, of course, it is necessary to have industrial firms who are likewise committed—willing to provide funds, maybe $50,000 to $100,000 each per year, for a sustained period."

Success at MIT has led NSF to try to duplicate its program at other universities. It now is backing eight other centers with funding ranging from $200,000 to $400,000 each. One of these, at the University of Massachusetts, also is involved with research on polymers; it has 13 industrial affiliates, each of whom contributes $20,000 a year, and gets about $250,000 from NSF. Colton believes it is about half-way to the point where it can support itself without NSF funding. Others are at Rensselaer Polytechnic, Kent State, Case Western Reserve, the University of Kansas, Ohio State, Worcester Polytechnic, and Catholic University. All of these are expected to become essentially self-supporting (requiring federal funds for less than 25% of their total budget) within five years of organization. Colton thinks that for at least some of the centers continuing NSF involvement—to help support graduate students, buy equipment, and take care of some overhead—may be needed on a limited scale. Total NSF spending for such centers this year will be $4 million to $5 million, part of which will go to support a somewhat parallel group (six at present) of university-based innovation centers, which concentrate on the needs of small new businesses. The innovation centers are set up to do research on entrepreneurship, provide training in managing small firms, and assist fledgling businesses.

NSF backs collaboration in research

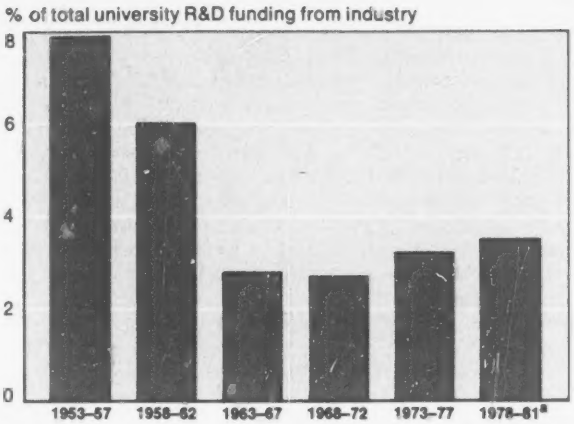
NSF's industry/university cooperative (IUC) research program is a more recent experiment, set up three years ago to encourage, by means of grants, more effective cooperation and communication between scientists in industry and those in universities. The program started with eight projects in 1978 that were funded for a total of about $1 million. In the fiscal year ended last September, 74 cooperative projects received more than $6 million in NSF funds. During the current year, the IUC program hopes to back more than 100 projects, for a total outlay of $15 million to $16 million, according to Frederick Betz, who heads the program.

Not all this money comes from the IUC budget itself. The prime consideration for NSF support is that the cooperative research projects deal with first-rate scientific problems. Hence the grants are made jointly by IUC and whichever NSF division is responsible for the area of science or engineering involved. For example, a proposal dealing with a project in chemistry would have to pass muster with NSF's chemistry division—by going through the usual NSF peer review system—before it could win approval. Then support would come from both the chemistry division and the IUC program. Typically, about two thirds of the grant is provided by IUC. Grants are usually roughly $100,000 a year for a two- to three-year period.

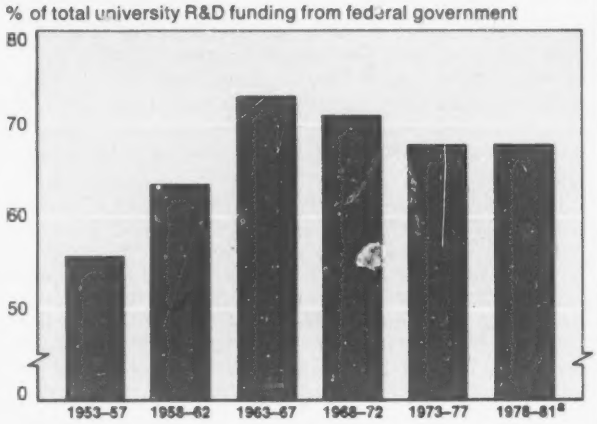
Proposals are judged not only on the basis of scientific quality, however, but also on the likelihood of effective collaboration between university and industry researchers. NSF funds are to cover the university's share of the project's cost; companies must ante up between 10% (for small businesses) to 100% of their share. In addition, companies must be actively involved in the research, so that there will be direct and equal collaboration between the university and the industrial scientists. In some cases, one award actually will cover two parallel projects, one run in a university lab and the other in the company's facilities. Proposals must be submitted by both participants. NSF also requires that results be published quickly in a scientific journal.

So far, the IUC program has generated more interest from the universities than from industry. Aerospace firms were generally the first to be attracted, but Betz claims that more and more chemical companies are getting involved. About 27% of the 74 fiscal 1980 awards were for research in materials science, including polymers. However, 16% were for chemical engineering projects and 9% were in chemistry. Perhaps the most successful project so far, though, involves work on new catalysts for a reversible oxygen electrode, a project involving Stanford University, California Institute of Technology, and Hercules. Other chemical projects include a joint investigation of intracavity laser spectroscopy by Illinois Tech

Industry's share of academic R&D support has declined from 1950's...



...and federal government's share has fallen more recently



a Estimate. **Note:** Data exclude R&D performed at federal R&D centers administered by universities. **Source:** National Science Foundation

and Bell Laboratories, and work on computer identification of mass spectra at Cornell and Hewlett-Packard. Typical chemical engineering projects include studies of membrane reactors done jointly at the University of Pennsylvania and General Electric, and an examination of hydrosulfurization catalysts being carried out by Cornell and Atlantic Richfield.

Two other government-funded programs that are likely to stimulate cooperation between industrial and academic research groups are still on the drawing boards. The Department of Commerce has plans to back the establishment of several cooperative generic technology centers in collaboration with other federal agencies, industrial firms, local government bodies, and other interested parties. These centers are to be designed to do research on technologies that cut across several scientific disciplines and would be valuable to a range of industries.

Commerce, which hopes to be able to spend about $5 million on the program during the current fiscal year, is studying proposals to set up centers to deal with such areas as computer-integrated processing techniques, welding and joining, powder metals processing, and friction and lubrication. The first center to be authorized—just last month—is to be established in Detroit to work on new computer-integrated techniques for forming metals, with initial funding of $1 million from the Commerce program. The plan is that Commerce will supply most of the seed money to get such centers started, then reduce its involvement gradually so that it would be supplying only about 20% of the funds after five years, with industry picking up the balance. What the role of the universities will be in this program is still uncertain, but according to Frederick L. Haynes, who heads the program under assistant secretary for science and technology Jordan J. Baruch, the centers will be encouraged to work closely with academic researchers.

Cooperation for automotive research

The Cooperative Automotive Research Program (which carries the rather unfortunate acronym CARP) will funnel money from the U.S. automobile manufacturers and the Department of Transportation into basic research on automotive technology needed for the 1990's. Unlike the generic technology center program, the aim is not to set up new research facilities but to support basic new work in existing labs, in industry, government, and the universities. The proposal calls for a federal investment of $12 million to get the program going in fiscal 1981, with funding rising to a total of $100 million in five years or so, split equally between the government and the auto industry. Most of the federal funds and part of the industry money will support university research.

These government efforts to encourage industry-academic cooperation have met with mixed reception from their intended beneficiaries. The generic technology center program, for one, has so far drawn scant interest from chemical firms, perhaps because they already are relatively sophisticated in their approach to R&D. It and CARP have been criticized for being too big and cumbersome, involving more participants than can work together effectively. Some critics, too, contend that these big-scale endeavors will be unresponsive to industry's real needs and difficult to close down if they are unsuccessful. On the other hand, the size of the generic centers may make them difficult to sustain by industry sponsors alone for the extended period necessary to generate economically useful results from basic research.

As Edward K. David Jr., president of Exxon Research, has noted: "There may be a few cases where federally inspired generic research could be productive. But these instances will be overwhelmed by the number of failures. The minimum requirement for generic research to be successful is that it have enthusiastic industrial involvement, fine leadership and management, and excellent research people. Such a conjunction will be rare. CARP and other massive proposals do not recognize these requirements."

The auto makers, too, have not been overwhelmingly enthusiastic about CARP, although all of them have now agreed to participate. General Motors, in particular, has indicated concern about the antitrust implications of the program, although both the Justice Department and the Federal Trade Commission have given it their blessing—as long as it restricts its work to "basic" research.

In any event, the fate of both the generic research centers and CARP now hinges on the policies the new Republican Administration evolves regarding science and technology when it takes office next month.

Even the more modest NSF programs have their critics. Some scientists see them as merely inserting an unneeded and costly layer of bureaucracy between the schools and the companies, and encumbering cooperative

research projects with wasteful red tape and review procedures. To which Colton responds, "If industry-university cooperation had been taking place without government intervention, fine. Maybe in 10 years, it will. But it wasn't happening very often before we launched our program; in fact, it's only beginning to happen now."

Exxon funds research on combustion

That it is, indeed, beginning to happen on a larger and broader scale is certainly evident. Exxon's recent agreement with MIT for combustion research, for example, meets the criteria many observers say are necessary for successful industry-university collaboration: direct people-to-people relations and extended support. As Alan Schriesheim, general manager of engineering technology for Exxon Research & Engineering, puts it, "Just sending money, without people, doesn't work very well." Adds Peter J. Lucchesi, Exxon Research's vice president for corporate research, "We are primarily interested in the researchers who make up academic centers of excellence, rather than the institutions as such. Our focus is on people, because the whole thing depends on whether you can find a true partnership with some academic group which wants to work with your group."

Exxon will provide MIT a total of $7 million to $8 million over a period of 10 years to study such problems as the burning of coal and coal liquids, shale oil, and heavy crude oil. The object is to develop more efficient fuels. Exxon selects specific projects from a list of proposals generated by the university, and the professors involved will devote at least half their time to these projects. However, MIT can use 20% of the funds available at its discretion for other combustion studies.

MIT will be able to patent results of the work, with Exxon getting a nonexclusive, royalty-free license to use the patents. Exxon and MIT will share any license fees from other users.

This arrangement is similar to Monsanto's 12-year collaborative research project with Harvard, which now is at the half-way mark. Monsanto supplies both money and technology to support Harvard's fundamental research on the biology and biochemistry of organ development. For example, it provides services and large-scale quantities of experimental materials from its research, analytical, and pilot plant programs that Harvard would be unable to produce or buy on its own. Monsanto researchers also work in parallel in their own labs in St. Louis with the Harvard scientists, and ideas and information are exchanged freely. Thus, Monsanto has a window on the current world of biological and medical research, as well as help in building its own research capabilities in areas where it had not been active earlier.

Harvard researchers, in turn, can carry out their work as they see fit and are free to publish their findings. So far, about 100 publications have come out of the program. They also can patent results of the work they do, with Monsanto having an exclusive right for a limited period to commercialize useful products growing out of the research. One unusual aspect of the agreement is an advisory board, whose members have no formal connections with either Harvard or Monsanto, set up to ensure that public interests be served.

Work to date has centered on the mechanism and structural/functional relationships of macromolecules such as proteins which serve as catalysts in hormonal and similar functions in the body. The program continued work previously under way at Harvard on the proliferation of blood vessels, including a study of tumor angiogenesis factor. This substance is thought to be produced by tumors and may play a role in inducing the body to build the new networks of blood vessels needed to support tumor growth.

In addition to one-on-one arrangements such as these, a number of programs have sprung up in recent years by which several companies jointly support university research.

One that has attracted a wide participation from chemical companies is the Center for Catalytic Science & Technology at the University of Delaware. The center evolved out of Delaware's chemical engineering department when Prof. James R. Katzer was seeking money to buy large equipment for catalysis research and talked with some local chemical companies. It started in the spring of 1977, with nine industrial sponsors and some funds from NSF for equipment, to do long-range fundamental research in catalysis problems of interest to industry.

The center now has 20 sponsors, most of them either chemical or petroleum companies, each of whom provides $25,000 a year. In return, they have access to all the research done at the center (except for some proprietary work). A strong interaction between the center and its sponsors is the key to its success, according to Katzer. Company people can spend sabbatical periods ranging from three months up to a year working at the center, as well as attend an annual research review conference. Each company has one representative on the center's advisory board, which can offer suggestions regarding research projects or criticize them. The board has no veto power over the work, however; the final decision on what work to do rests with the center's staff. Typical projects include catalytic hydroprocessing of coal liquids, development of polymer- and metal-supported catalysts, and spectroscopic studies of the catalytic process in situ. Delaware owns many patents stemming from such work, which are made available to any of the industrial affiliates.

The major problem the center has run into, according to W. F. Howard Jr., its assistant director, lies in interacting with 20 different partners. "It's a heavy drain on our time to respond to so many people," he notes. Therefore, the center is not now actively recruiting new affiliates, although it never so far has turned anyone down.

Although the center is an outgrowth of Delaware's chemical engineering department, it is interested in getting the university's chemistry department more involved with its work, which basically is applied chemistry. Most of its 10 postdoctoral staff members have chemistry degrees. And it is funding some research by the chemistry faculty.

A new source of industry funds

Several research executives in the chemical industry have become convinced that if it is to foster the basic research it needs, something more is needed than such direct company-school arrangements as Monsanto's agreement with Harvard or Delaware's cooperative program in catalysis. One proposal that has excited many of them calls for the establishment of an industrywide organization that would promote academic-industry cooperation and provide a new source of money for university research.

The proposal was initially broached in October 1979 by M. E. (Mac) Pruitt, then vice president for research and development at Dow Chemical (and now retired). At a scientific conference sponsored by Dow that brought together in Midland, Mich., a large number of university professors and industrial research officials, Pruitt suggested that an institute formed to collect industry funds and dole them out to the universities was "something that

ought to be looked at." Pruitt argued that such an organization "would provide a more stable long-range funding mechanism" and "build closer cooperation between the chemical industry and academic research."

At the end of the Midland conference, it was decided to hold a second conference a year later, and a task force was formed to follow up on Pruitt's suggestion. The second conference was held last September in Bethlehem, Pa., with Air Products & Chemicals and Lehigh University serving as cohosts. It attracted attendees from more than 90 universities and about 40 companies, as well as several government research officials.

They learned of a rather detailed plan put together by the task force to form a Chemical Research Council (CRC). Its key objective would be "to provide colleges and universities with new, significant, and continuing sources of funding for basic research of potential value to the chemical industry." Other goals: "to promote mutual understanding and cooperation between academe and the chemical industry," to improve "the national climate for creativity and innovation," and to "promote the education of highly qualified science and engineering professionals."

Primarily, CRC would serve as a new forum for industry-university collaboration. As Pruitt puts it, "Much talk has gone on for the past couple of years about the need for a cooperative effort between industry and universities, but there has been no vehicle or mechanism for bringing this about." He adds, "Industry must provide more funds to the universities. And the universities must show more interest in the problems and basic needs of the chemical industry. As we move along this cooperative path together, funding has to be an essential part of our program."

Members of CRC would be both academic institutions and companies "engaged in research of potential interest to the chemical industry." They will be represented by deans of science or engineering schools and heads of science or engineering departments in the case of universities and by vice presidents or directors of research in the case of companies. Each member institution will have one voting representative and as many as three alternates who also can attend the council's functions. For universities, dues will be $1000 a year for the voting representative and $500 for alternate representatives; companies will pay $5000 a year for their voting representative and $2500 a year for any alternate. The council would study such issues as new ways to stimulate university research, manpower supply and demand problems, government policies regarding research, and the conflict between schools and companies regarding patent and publication policies.

But the glue or catalyst that many of CRC's advocates think will really make it viable is a second proposed organization, a Chemical Industry Research Fund, to be set up within CRC. Industry members would be asked to contribute to the fund, which would be used to support basic research in universities. The goal is to make an ambitious $10 million a year available within three years after the fund is established. Just how this money is to be collected and distributed is still being thrashed out. One suggestion is that companies contribute to it at a rate of 0.015% of their annual chemical sales, with a minimum of $100,000 and a firm commitment for no less than three years. A board of trustees, two thirds of whose members would be selected from companies that contribute to the fund and one third from academic members of CRC, would oversee the fund. (The governing board of CRC itself will be made up equally of industry and university representatives.) Grants from the fund would be made either to individuals—at the rate of up to $30,000 for a period of three to five years—or to several investigators in amounts ranging as high as $200,000. It also has been suggested that money be made available to facilitate personnel exchange and cooperative programs or for improving laboratory facilities.

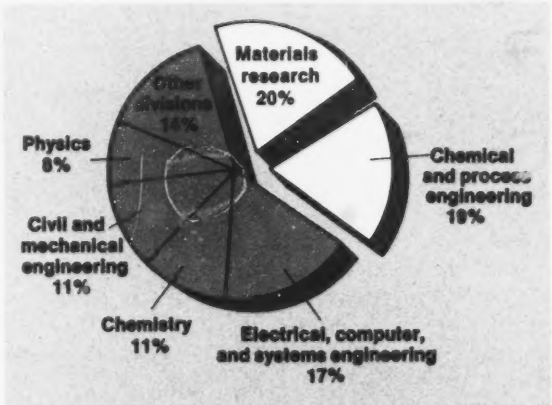
Reaction to the CRC proposal generally was favorable at the Bethlehem conference, especially from university people in attendance. Many of them did urge, however, that the fund find some means of distributing its money in ways different from that used by such established sources as NSF or the Petroleum Research Fund. Several think that grants should be more people-oriented—that is, made to exceptional individuals, especially young professors, for use at their discretion rather than for specific projects subject to peer review. Other academics expressed the need for assurance that money channeled through the fund be in addition to rather than as a substitute for support already available.

Whether CRC can be sold to the top executives and directors of chemical companies is yet to be determined. Many companies are likely to insist they need more control over the way their basic research dollars are spent than CRC provides and prefer one-on-one relations with academic recipients. There also are questions about whether a new permanent organization really is needed to support basic science.

But there is no question that CRC has a lot of enthusiastic supporters at high places in both the academic and industrial worlds. They see it as an effective new way not only to couple industry funds to university labs but to enhance the flow of information and understanding as well. A founding committee was selected at the Bethlehem conference to hammer out a final charter for the organization. Its 12 members, split evenly between industry and academic officials, have met twice since then, set up a number of subcommittees to handle various organizational details, and selected a counsel to help them iron out legal aspects. They hope to have some concrete plans in place when a third conference on the matter meets next September at Rochester, N.Y., with Eastman Kodak and the University of Rochester as hosts.

These plans may differ considerably from what was proposed at the Bethlehem conference. The research fund concept, in particular, may be much modified, perhaps to something less ambitious or less centralized. Companies may be more receptive to CRC, some ob-

Materials, chemical engineering get big share of NSF funds for co-op research



Total funding for industry/university cooperative research program, fiscal 1980 — $6.2 million

Source: National Science Foundation

C&EN staff photo

Pruitt: academic researchers can get involved with industry without losing their academic freedom

servers think, if its role is more that of a broker that would bring its industry and academic clients together to discuss needs and problems of mutual concern, thereby encouraging the flow of research support from companies to campus without necessarily acting as a direct conduit for that support. Despite the continuing debate about how it is to be implemented, however, chances seem good that at least a paper CRC may be in place by next year.

One thing does ring clear in current efforts to form CRC: There is little if any mandate for government to have a direct role in its functions. In fact, a definite consensus seems apparent among both university researchers and industry people that new procedures for backing academic research—ones that would ease its present dependence on federal largesse—now are highly desirable. Although NSF's industry/university cooperative programs generally win praise, dissatisfaction with the federal role in supporting R&D, with its emphasis on project funding on a peer review basis, appears to be widespread. When it comes to innovation and practical application, many see little fallout from federally funded projects except when (as is the case with defense or space programs) the government has some real use for the results.

Many industry executives have been arguing, in fact, that the most effective step the federal government could take now to stimulate university research is to enact tax incentives that would encourage industry to funnel more dollars to the campus. One suggestion in particular, the proposed Research Revitalization Act (H.R. 6632), has garnered broad industrial approval. Under it, companies would win a tax credit of 25% on money they put into a reserve to fund university research. In effect, the credit would cut the cost of industry's support of such research in half. The bill to do this was introduced by Rep. Charles A. Vanik (D.-Ohio) this year, gained considerable backing from other members of Congress, but made little progress. Vanik is retiring from the House at the end of the current session, but similar legislation is likely to be introduced again next year.

It is still far too early to judge whether all the activity on the industry-academic interface really portends a significant change for either private companies or the universities. Misunderstanding still runs deep on both sides. And just a lack of recognized mutual interests has deterred communication. For industry, the bottom line is profits; for the universities it is the number and quality of its graduates and the productivity of its research. In industry, attaining a competitive edge depends on moving swiftly and keeping competitors in the dark; in the universities, time is not of the essence but freedom to exchange information is. The reputation of a professor depends not just on what he or she knows but on the opportunities for letting colleagues know that he or she knows it. The inherent tension between industry's single-minded pursuit of income and the universities' penchant for diversity and redundancy, between the essential openness of the academic community and the essential need of companies to protect their proprietary knowledge will not be eased readily.

Overall mistrust, too, still is widespread. It is worth noting that much of the concrete cooperation that has taken place during the past few years has involved engineering schools, which traditionally have been a few steps closer to industry, more so than science departments. Writing in *The Nation* last Sept. 20, David F. Noble, who teaches the history of technology at MIT, and Nancy E. Pfund, research associate at Stanford medical school, warn of businessmen's attempts to co-opt university-based experts in order to bestow ideological sanction and scientific legitimacy upon industry's campaign against government interference. Academic freedom now is up for sale, they fear. "With industrial support," they write, "the primary consideration guiding university funding is not social need but rather the profit needs of the firm itself. Moreover, the firm, in purchasing access to the university's resources, is blocking access to others and has no obligation to share that access. . . . And the industry is getting far more than it is paying for: It is getting the cumulative social investment—one that took decades and sometimes centuries to create—in return for little more than operating expenses." Monsanto's agreement with Harvard, they argue, for example, "has in essence transformed a part of a public-sector social resource into a private-sector preserve, with little public scrutiny or accountability over its use."

That industry overtures are only self-serving, that companies want access to the campus at only a minimum of cost and offer little in return is a common professorial reaction. "We don't mind companies coming to visit, but somebody better count the silver before they leave," says one academician.

Nevertheless, there is no ignoring the groundswell of recognition that companies and the academic world have much to gain from mutual endeavors. "I believe academic researchers can get involved with industry without losing their academic freedom," says Mac Pruitt. Adds Celanese's Al Brown, "There isn't a university I could visit where I wouldn't learn something of value." What has been happening recently to bind industrial and academic research more strongly together is still largely in the nature of experiments. The experiments so far have yielded little in definite results. But they are being widely discussed. And that in itself is no bad thing as a step toward easing a long-standing estrangement. □

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December 15, 1980

Solvents producers will get little relief in 1981 Page 8

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Chemical warfare

Build up or disarm? Page 22

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Chemical & Engineering NEWS

Cover: Soviet soldier training in chemical warfare protection gear. Photo courtesy of U.S. Department of Defense

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Overcapacity clouds outlook for solvents

Acetone, ethanol, methylene chloride face rocky time in 1982 before recovery really gets under way late in year; eventual pickup will be slow

U.S. producers of major organic solvents struggled through a confusing, pollution-plagued decade in the 1970's, winding up with annual overall production volume lower than when the decade began. The 1980's have followed with a sharp recession the opening year, a downturn which in some respects has still not ended for solvents makers.

That's not an auspicious start for the decade, and the solvents industry is resigned to a rocky beginning in 1981 before a slow recovery late in the year. Production for the three solvents covered in the following pages—acetone, ethanol, and methylene chloride—is expected up optimistically 8% in 1981 to a combined 4.3 billion lb, after an 11% decline to 4.0 billion lb in 1980 worth just over $1.1 billion.

Plant operating rates can't move up much in 1981, possibly to an average 70% of nameplate capacity from 68% in 1980. That's way below average plant use of 82% in a more prosperous 1979—too far below to promise much in the way of profit.

One reason is that producers are still pushing up plant capacity. Combined capacity for the three solvents has increased another 3% in 1980 after 7% in 1979. The resulting excess will discourage new investment in solvents for some time to come, helping to make the group one of the least attractive businesses in the chemical industry.

So in some respects, solvents would appear to have a grim "more of the same" prospect for the next several years. The pollution problems which dragged down markets in the 1970's haven't gone away fully, and solvents are facing more potential problems from toxicity.

However, under the drab current statistics, some of these compounds have a lot going on with the possibility of some dramatic changes by the mid-1980's. The most apparent is ethanol, which is drawing hundreds of millions of new investment dollars for a nonsolvent, fermentation-process future in gasohol, the 10% mixture of ethanol in gasoline.

Although currently surviving only on the strength of government tax subsidies, fermentation ethanol has enthusiastic backers, especially in the oil and corn wet milling industries. A potential danger already realized in small transactions is excess of fermentation ethanol hitting synthetic ethanol markets if gasohol doesn't live up to expectations or if necessary subsidies fall short.

A similar dramatic process change may await the largest acetone derivatives market in methyl methacrylate. Although the effect would be bad for acetone, the possibility is considered remote at present. The new process would use isobutylene instead of acetone as feedstock. However, the value of isobutylene has been pushed too high for such a switch from low-valued acetone by the meteoric growth of an alternative use in making methyl *tert*-butyl ether, the new gasoline octane booster. Economics eventually could change if MTBE's new importance causes oil refiners to build new butane isomerization units to increase feedstock supply.

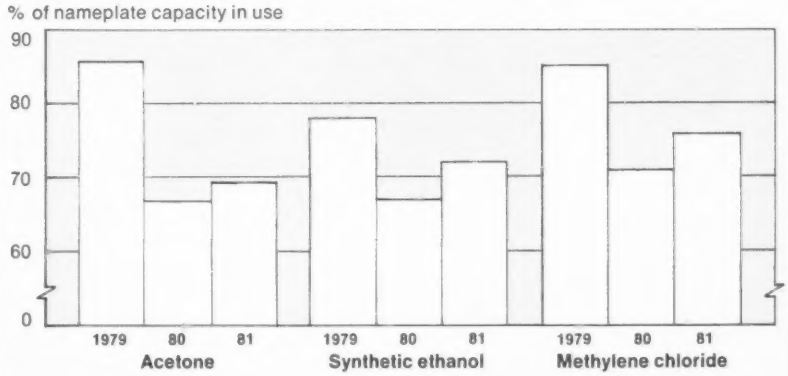
These two potential alternative processes point to two general complications which make life difficult in the solvents business—extensive intruding economic influence from other chemicals, including competing solvents, and strong influence from fuel markets. The most obvious example of the first problem is production of acetone, which puts acetone second fiddle to coproduct phenol. When phenol demand is poor as at present, acetone coproduct is also held down, drawing out more acetone production from competing plants making acetone from isopropyl alcohol. Hence, phenol's woes will continue to be good news to isopropyl alcohol, and acetone plants based on that compound may have a good year in store.

This leads directly to the second complication, solvents' strong economic ties to the fuel industry. For acetone, the value of feedstocks as octane boosters in competing gasoline markets has a strong effect on the ranking of feedstocks for acetone. Current economics favor isopropyl alcohol, weigh a bit against aromatics leading to the phenol-acetone route, and rule out isobutylene. This lineup could change in the future but not in 1981.

In short, few commodity product lines beat solvents for complexity. The net result has been a tattered business in the past several years, with companies betting wrong in substantial new plant capacity. It will take a while to absorb the profits penalty.

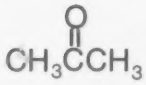
Bruce Greek, Houston, and William Fallwell, New York

Solvents' capacity use won't recover very much in 1981



Sources: Industry, C&EN estimates

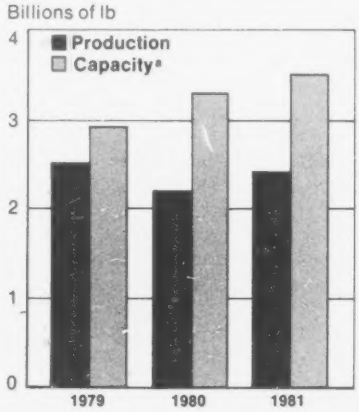
Key Chemicals



Acetone

- ***Demand better***
- ***Capacity up a bit***
- ***Prices to rise***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Coproduction with phenol by oxidation of cumene; dehydrogenation of isopropyl alcohol

MAJOR DERIVATIVES

Methyl and other methacrylates 30%, methyl isobutyl ketone 10%

MAJOR END USES

Solvents, alone or as derivatives, 60%; fabricated plastics 30%

FOREIGN TRADE

Exports—rising some to about 250 million lb in 1980, imports—negligible

PRICES

Contracts 29 cents per lb as of Jan. 1, 1981; some discounting

COMMERCIAL VALUE

$600 million for total production, 1980

Acetone is coming slowly out of a dismal year. As with most other organic chemicals made in the U.S., production of acetone dropped abruptly in 1980 just after plant capacity increased in 1979. The capacity increase exceeded normal product growth even without the production decline. As a result, plant operating levels dropped to a very low point in 1980. And producers don't have their hopes up for 1981 either.

Even if production increases a bit as demand improves and prices recover in 1981, another year will pass before production makes it back to previous highs. Production is expected to rise 10% in 1981 after a 15% decline in 1980.

As the fourth quarter of 1980 opened, production of acetone showed hopeful signs. Some forecasts turned more optimistic, giving a net year-to-year decline of less than 10%. Production in 1980 would then top 2.4 billion lb.

However, the reversal in housing starts over the past month or so—bad news for coproduct phenol—has dashed such optimistic forecasts. Estimates for acetone production are now back to 2.2 billion lb or a bit less for the year.

The new weakness in phenol demand, the controlling factor in production of both phenol and acetone from cumene, now makes the 1981 outlook for acetone from this source weaker than once expected.

If acetone production in 1981 manages to rise 200 million lb or so, the increase will about equal capacity added in 1980. The result will be that nameplate capacity was run at a not very profitable 69% rate. This pace would hardly beat the recessionary rate in 1980.

Actual capacity use will be a bit higher, since about 300 million lb of capacity currently is shut down as the result of an accident in a cumene unit at Shell Chemical at Deer Park, Tex. With this capacity excluded, the operating rates for 1980 and 1981 would be about six percentage points higher. Shell's unit is being rebuilt and could be on stream again in second-half 1981.

This accident, plus the slow demand for phenol in plywood adhesives, has changed process relationships for acetone in 1980. About two thirds of acetone capacity uses the cumene-to-phenol/acetone route. However, industry sources estimate that actual acetone production will be just over half from this route and the remainder from the isopropyl alcohol-to-acetone route. Depending on the U.S. economy, especially housing and light commercial construction, the 1981 production mix will again tend toward an abnormally high fraction from isopropyl alcohol.

Cost pressures might add to the disproportionate use of isopropyl alcohol as raw material for acetone. Since alternative cumene comes from aromatic streams of oil refineries in strong demand for gasoline, cumene's cost may rise faster than that of isopropyl alcohol. Isopropyl alcohol is based on chemical-grade propylene, which also comes from refineries but is not so attractive for gasoline.

Cost pressures of another kind also tend to work against the cumene route for acetone. In general, storage capacity for phenol is small because it requires safeguards adding to ordinary storage expense. To avoid such costs, even if signs appeared of an imminent improvement in phenol demand, producers would tend to fit production close to demand. This means that unexpected demand for acetone inventories would tend to be filled from material based on isopropyl alcohol.

Unfortunately for acetone, such production economics unduly affect output, and demand rarely dominates. However, market forces still exist. Solvent uses account for more than half of total demand for acetone, if derivatives are included. Both price and properties have some impact on this solvent demand. For example, when phenol demand is high, acetone production runs high and its price weakens. So it may partly replace other solvents.

After solvents, the next largest use of acetone is in making methyl methacrylate (MMA) and higher methacrylates. This use of acetone once appeared to be threatened by new MMA technology based on isobutylene. This threat has receded because of the increased value of isobutylene in making methyl *tert*-butyl ethers, the octane improver for gasoline. If this process switchover for acetone finally materializes, it will be the mid-1980's before it will have much impact on production.

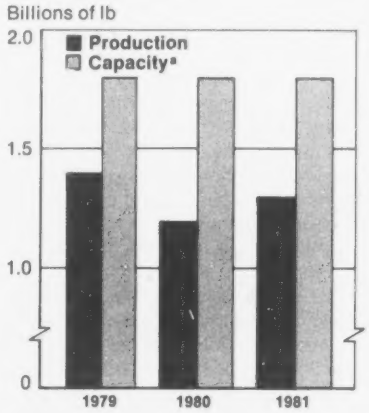
Key Chemicals

Ethanol

CH_3CH_2OH

- ***Demand sluggish***
- ***Capacity flat***
- ***Prices steady***

PRODUCTION/CAPACITY



a Synthetic only as of first quarter.

HOW MADE

Hydration of ethylene

MAJOR DERIVATIVES

Ethyl acetate and other esters 15%, ethyl amines 5%, glycol ethers 5%

MAJOR END USES

Solvents, alone or as derivatives, 85%; food 10%

FOREIGN TRADE

Exports and imports very small

PRICES

$1.93 per gal (6.8 lb) for 190 proof, $2.07 per gal (6.6 lb) for 200 proof as of Jan. 1, 1981

COMMERCIAL VALUE

$335 million for total production, 1980

Synthetic ethanol's doldrums continue while fortunes seem to rise for fermentation ethanol in gasohol. The divergence of these two types of ethanol in the U.S. probably will continue for some time.

Because synthetic ethanol goes almost entirely to industrial markets, its 1980 production decline reflects the impact of the recession. Market forecasters say synthetic ethanol production will be about 1.2 billion lb, or 180 million gal this year, off 16% from 1979 production.

The outlook for 1981 isn't much better. Production of synthetic ethanol is expected to increase modestly to about 1.3 billion lb, or 190 million gal. Such an increase will be less than the 1980 decline in production, thereby leaving a two-year gap in new growth.

Fortunately for synthetic ethanol producers, no plant capacity additions have arrived recently or will arrive in 1981. Capacity has been declining as units were shut down and coproduction from other organic synthesis discontinued.

If production of synthetic ethanol in 1980 reaches the forecast 1.2 billion lb, nameplate plant capacity of 1.8 billion lb will be run at about 67%. Next year's operating rate will be slightly better, perhaps 72%. But long-term prospects are that production growth will be slow, perhaps 5% in a good year. Under these circumstances, the need for additional capacity remains remote, especially if imports resume or fermentation-based ethanol moves into industrial markets because demand for gasohol proves too low.

By contrast, capacity is growing meteorically for fermentation ethanol going to fuel use as gasohol, usually a mixture of 10% ethanol and 90% gasoline. Subsidies from the federal government, either real or potential, combine with process advantages as an economically attractive adjunct to corn wet milling with possible use of coproduct carbon dioxide in enhanced recovery of crude oil to spur building of big units for fermentation ethanol.

Coming fermentation ethanol capacity in various stages of startup, construction, or planning could add more than 750 million lb per year to the fermentation ethanol total, about doubling it. However, some of the current capacity claimed as operable may be in such bad condition that it is out of the picture. And, should government incentives be rescinded or prove too small on closer checking, new fermentation capacity could be much smaller than expected.

Even now, gasohol costs the user more than does high-octane unleaded gasoline unless the seller is taking a loss in hopes of recouping later. Because of this cost problem, some quantities of fermentation ethanol are rumored entering the spot market for industrial uses, selling 10% or so below the current industrial selling prices even after temporary voluntary allowances (discounts) in synthetic ethanol contracts.

Currently, the standard contract price for synthetic ethanol is $1.88 per gal for 190 proof (95%). Most allowances are 5 cents a gal, bringing actual selling prices to $1.83 a gal. A split price may be in the offering, since Union Carbide has posted a nondiscounted $1.93 tag for Jan. 1.

The cost outlook of synthetic ethanol can be only far higher prices because of its link to basic hydrocarbon costs (oil and natural gas). A bit under two thirds of a pound of ethylene is needed to make a pound of ethanol. In a gallon of ethanol, the ethylene cost is about $1.00. Considering processing costs to make ethanol plus overhead and return on investment, producers are not doing well at present contract selling prices.

The substantial overcapacity for synthetic ethanol probably precludes any change in the profitability outlook for 1981. Demand is expected to change little.

Solvent uses of one kind or another account for most of ethanol's consumption. Some of these solvents are chemical derivatives of ethanol, designed to do special jobs or provide improved properties. Because most of these solvent uses, such as in personal care products and industrial operations, are mature, little change will occur.

The outlook for synthetic ethanol remains, as in the past several years, minor change and low profits reflecting outside economic conditions. Fermentation alcohol will have enthusiastic investors but underlying cost problems are a big question mark for the long run.

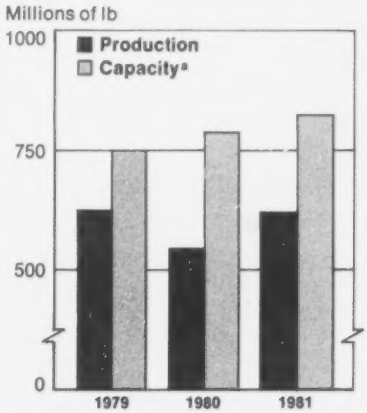
Key Chemicals

CH_2Cl_2

Methylene chloride

- ***Demand up a bit***
- ***Capacity adequate***
- ***Prices rising***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Chlorination of methane; hydrochlorination of methanol followed by chlorination of methyl chloride

MAJOR DERIVATIVES

None of any volume

MAJOR END USES

Paint remover 30%, aerosol propellants 20%, degreaser 10%

FOREIGN TRADE

Exports—steady, about 75 million lb in 1980; imports—small, about 30 million lb

PRICES

30.5 cents per lb, Jan. 1, 1981

COMMERCIAL VALUE

$150 million for total production, 1980

Methylene chloride, like other chlorinated methanes in the U.S., continues to have its ups and downs. In 1980, the direction is down, and in 1981, not up enough. Production and sales are off in 1980, while capacity growth has fortunately slowed.

Methylene chloride production in 1980 probably will reach 550 million lb, down more than 13% from 1979. Last year's output of 635 million lb was a record that finally exceeded 1974 production of 608 million lb.

Forecasts for 1981 production of methylene chloride depend on how well recovery goes after a possible double-dip in the recession. Unless business improves much more than expected, 1981 output will do well to reach 625 million lb, but it could be as little as 600 million lb.

Plant capacity for methylene chloride varies considerably, since other chlorinated products can be made in the same production units. If estimates of about 775 million lb of operating capacity in first-quarter 1980 are correct, close to what producers have listed as nameplate totals, 1980 production dictates a low average plant operating rate of about 71%. This is typical for a large-volume organic chemical this year.

Capacity has continued to expand slowly as producers add units or debottleneck existing plants. Some of the "expansion" could be no more than a change in product mix to make more or less of various chlorinated methanes. Hence, the mathematical operating rate for a given chlorinated methane doesn't fully reflect how well or poorly that compound may be doing financially.

In 1981, expected recovery in methylene chloride demand after some capacity expansion in 1980 will push the plant operating rate to more than 75%. Hence, plenty of capacity will remain available to meet future demand growth. Capacity in first-quarter 1981 is expected to be 6% higher than a year ago to a new total of 825 million lb.

This excess capacity traces back to methylene chloride's promising growth until the 1970's. Good solvent properties, low corrosion effects, and nonflammability brought a steady surge for the product. Then the ups and downs began. Concern over general toxicity of chlorinated hydrocarbons may have had some impact on use of methylene chloride, both positive and negative. At this time, however, future use of methylene chloride seems more dependent on its general solvent properties than on its possible toxicity.

Of the various uses of methylene chloride, paint removers remain the largest, although dropping in market share. More than 30% of U.S.-consumed methylene chloride is going to this use in 1980.

Along with paint removers, degreasing solvents is another longtime use that may find its present 10% cut of the methylene chloride pie slowly slipping. However, the changes in degreasing solvent choice by users may help methylene chloride. Some competing chlorinated ethanes or ethylenes have fallen from favor for pollution reasons, making methylene chloride more attractive.

The most rapid growth in recent years among methylene chloride's uses has been as a propellant in aerosols. Since methylene chloride decomposes faster than do chlorofluorocarbons, it has gotten the nod as a replacement because of concern over chlorofluorocarbons' damage to the ozone layer in the upper atmosphere.

Use as an aerosol propellant has increased rapidly in the past few years to become the second largest outlet for methylene chloride with 20% of the total. Because the cost of methylene chloride is relatively high compared to simple hydrocarbon propellants, many propellant formulations contain both. Besides improving solvency, methylene chloride helps as a flame suppressant. Also it is much less expensive than chlorofluorocarbon propellants.

The properties making methylene chloride useful as a propellant also make it useful as a blowing agent in making polyurethane foams, another outlet with prospects for further growth. About 5% of methylene chloride goes to this use at present.

On balance, then, methylene chloride is having two years of no new growth, with plant operation well below optimum for profitability. Producers hope that after next year, methylene chloride will be able to break out of its recent ups and downs for another round of steady growth.

NOTE

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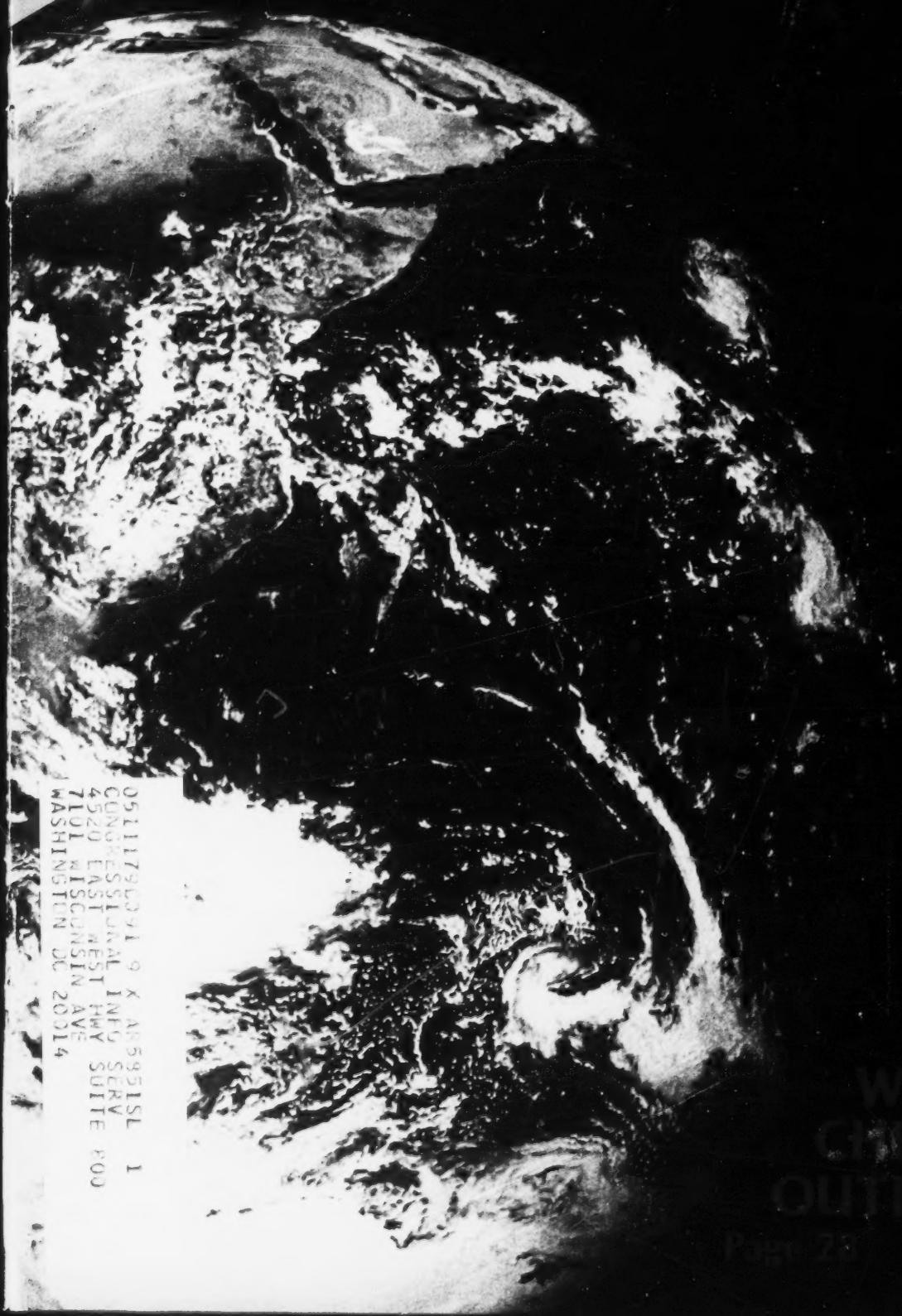

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- ***CMA is optimistic*** *that chemical business will improve next year.* ***Page 6***
- ***Congress probes organized crime's role*** *in illegal waste dumping.* ***Page 7***
- ***France's Rhône-Poulenc and U.S.S.R.*** *sign agreement for 10-year trade package totaling $6 billion.* ***Page 7***
- ***Health effects of auto exhaust*** *emissions will be studied by institute set up by EPA and auto industry.* ***Page 8***
- ***Industrial waste research center*** *formed by IIT and Notre Dame.* ***Page 8***

Business

- ***Pension funds for chemical workers*** *found to be more generous than retirement plans for all U.S. manufacturing.* ***Page 12***
- ***Alpha Products' new "production laboratory"*** *triples capacity to produce specialty and lab chemicals.* ***Page 13***

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- ***Main East-West technology flow*** *is from West to East; fastest growing item for East is turnkey arrangements.* ***Page 14***

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- ***Views on U.S.–U.S.S.R.*** *scientific cooperation given by Soviet scientist and State Department, NAS spokesmen.* ***Page 24***

World Chemical Outlook

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- ***Fred A. Tate*** *pioneered development of CAS Chemical Registry System and in making it international in scope.* ***Page 54***
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- ***C&EN's semiannual calendar*** *lists events of chemical interest in 1981.* ***Page 57***

RECORD R&D FUNDING PREDICTED BY BATTELLE

Expenditures for research and development in the U.S. will rise to record levels in 1981, Battelle Columbus Laboratories says in its annual R&D forecast.

According to Battelle economists Jules J. Duga and W. Halder Fisher, R&D outlays will reach $68.6 billion, an increase of 13.7% from the $60.4 billion that the National Science Foundation estimates actually was to be spent in 1980.

Most of the increase will be absorbed by continuing inflation, which Battelle predicts will amount to 9.9% in 1981. Real R&D expenditures will increase 3.8% from 1980 to 1981, or slightly more than the 3.4% average annual increase over the past seven years, the forecast says.

Patterns of R&D funding and spending will show little change from previous years, Battelle says. Federal support will increase 14.0% from the 1980 amount to about $33.7 billion, or 49.1% of the 1981 total. Industrial funding will increase 12.9% to about $32.4 billion, or 47.2% of the total. Academic institutions will provide about $1.4 billion (2.1% of the total) and other nonprofit organizations $1.1 billion (1.6%).

Industry will continue to do most of the work. In 1981, Battelle says, performance of R&D by industry is expected to rise to $48.0 billion, or 70.0% of the total. In-house federal research will amount to about $9 billion (13.1%). Performance of R&D by academic institutions will account for $9.1 billion (13.3%); by other nonprofit organizations, for $2.5 billion (3.6%).

Battelle notes that federal funds support R&D performance in all four sectors. About 25% goes to research carried on by the government itself; almost 50% goes to industry; about 20% goes to colleges and universities; the rest, less than 5%, goes to other nonprofit organizations.

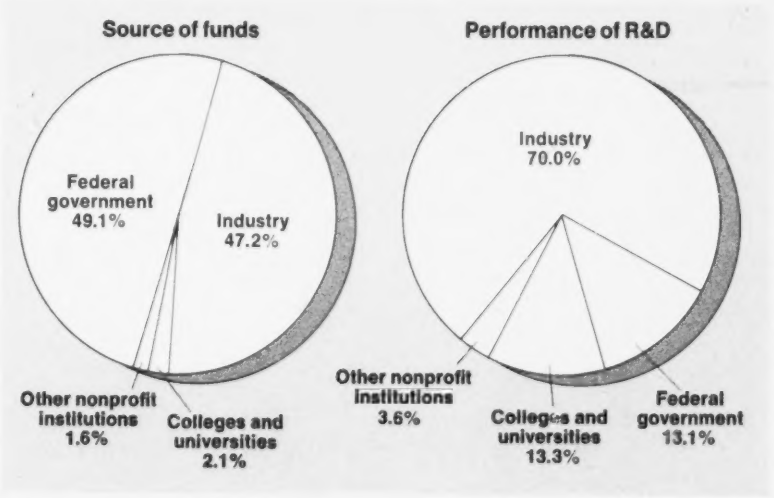
Four government agencies are expected to account for 86.7% of total federal R&D funding in 1981, Battelle says: Department of Defense, 45.0%; National Aeronautics & Space Administration, 15.7%; Department of Energy, 15.1%; and Department of Health & Human Services, 12.1%.

Industrial R&D support continues to grow, especially in fields affected by government regulation and in fields with the greatest need for more energy-efficient products and processes, Battelle says. In the manufacturing industries, R&D will be heavily self-funded, with only 32.9% of the total coming from the federal government.

Among manufacturing categories, the electrical machinery and communications sector will be the leader in total R&D, with 1981 expenditures of $10.8 billion, of which 44.0% will be federally supported, Battelle says. Aerospace R&D will decline somewhat, to about $9.8 billion, of which 80.1% will be federally supported. Chemical industry R&D will come to about $5.3 billion in 1981, but only 10.5% of that amount will be funded by the government.

Battelle anticipates that the incoming Reagan Administration may be friendlier to business than the old Administration and that it may provide an atmosphere more conducive to industrial R&D. In particular, greater effort likely will be devoted to both short- and long-term R&D aimed at improving the position of U.S. industries with respect to their foreign competitors. However, Battelle says, any initiatives proposed by the new Administration or Congress in 1981 won't have much effect until 1982 at the earliest. □

R&D funding to reach $68.6 billion in 1981



CMA optimistic on 1981 chemical business

The Chemical Manufacturers Association is relatively bullish on the outlook for chemicals in 1981, even though it sees a great probability of the U.S.'s sliding into a second leg of a double-dip recession during the first quarter.

At a press conference in New York City last week, Myron Foveaux, CMA trade and economic policy adviser, said that a survey of member companies shows that sales of chemicals and allied products will increase about 16% in 1981 to $186 billion, after an estimated increase of 7% in 1980. The survey also indicates that earnings will rise in 1981—18% to about $12.7 billion. This follows an estimated increase of 7.4% in 1980.

The survey is quite bullish on capital spending next year, too. CMA member companies say that investment in new plant and equipment will increase about 20% in 1981 to $11.5 billion. This is much more than the 8% increase found in a recent C&EN survey of 17 top basic chemical companies' capital spending plans for 1981 (C&EN, Dec. 8, page 19).

According to Foveaux, the CMA survey also found that R&D spending in 1981 will be about $4.75 billion, salaries will climb about 10%, and

Chemical pension funds better than average

Survey finds that retirement plans for chemical workers are more generous and appear to be safer than those for all manufacturing

Pension plans for U.S. chemical employees seem to be better funded, more generous, and safer than those for all U.S. manufacturing, according to a study by Johnson & Higgins, a New York City insurance firm. The firm reached its conclusions after surveying 1979 annual reports of Fortune 500 companies.

In 1979, manufacturing companies were more generous with their employees as far as pensions are concerned than they were in 1978. For 475 manufacturing companies surveyed, the average cost per employee last year rose 11.8% from 1978 to $1243.

Chemical companies contributed even more. The cost per employee for 36 chemical companies surveyed rose 14.3% in 1979 to $1402. In 1977, the average cost per employee for 474 manufacturing companies was $996. For 36 chemical companies, it was $1180. Of the 36 chemical companies surveyed, three increased average pension cost per employee more than 30%.

The average pension cost per company also increased substantially in 1979. For all manufacturing, the cost per company last year was $41.2 million, an increase of 15.7% from 1978. Chemical companies had a lower cost per company at $36.1 million than did manufacturing as a whole, but this seems to be because chemicals are a less labor-intensive industry than average. The increased cost per company for chemicals was greater, however, than that for all manufacturing. The $36.1 million pension cost average for chemical companies in 1979 was 17.5% more than the 1978 average.

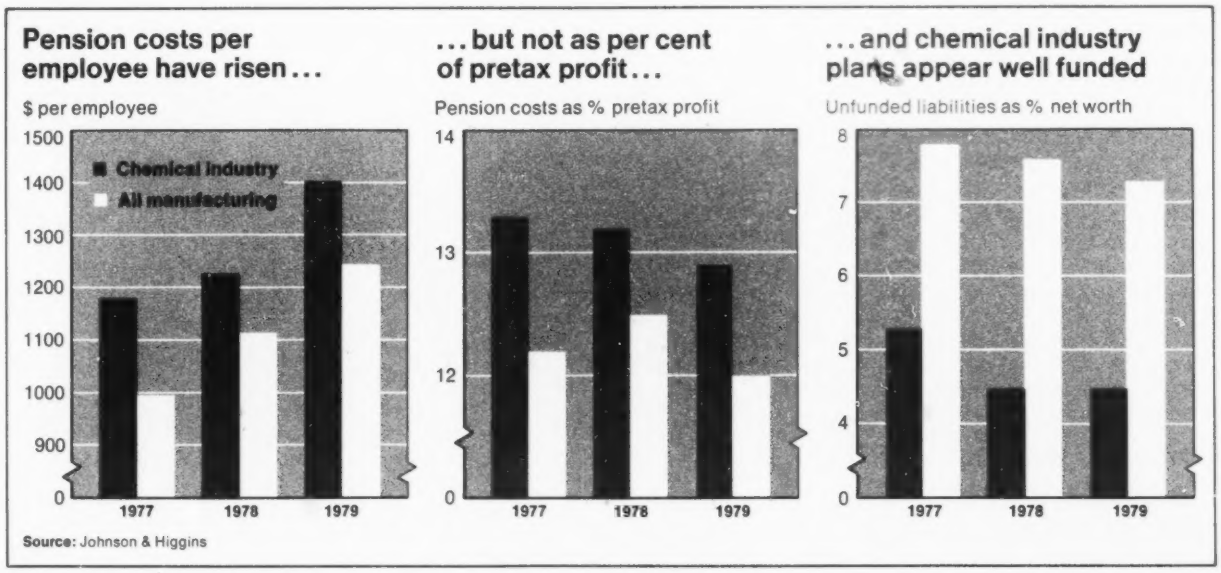
Pension costs as a percentage of pretax profits fell in 1979 from 1978 levels. For all manufacturing, pension costs' percentage of pretax profits was 12.0% in 1979 compared with 12.5% in 1978. For the U.S. chemical companies, the percentage fell to 12.9% in 1979 from 13.3% in 1978, according to the survey.

This drop was by no means caused by a leveling off of pension costs, however. The increase in pretax profits simply outpaced that for pension plan costs. While pension costs were rising an average of 15.7% per company for all manufacturing and 17.5% per company for chemicals, pretax profits were increasing 20.8% per company in 1979 for all manufacturing and a much larger 28.1% per company for chemicals.

In spite of the difference, Johnson & Higgins says, pension plan costs as a percentage of pretax profits were "remarkably consistent," costing the companies about one and one half months of pretax profits in both 1978 and 1979. This assumes an 8.3% monthly accrual rate for a 12-month fiscal year.

The pension plans for chemical companies seem to be safer than those for all manufacturing, although in real terms they are not very different. The Employee Retirement Income Security Act (ERISA) says that if a pension plan were to terminate with insufficient assets, up to 30% of the company's net worth can be used to fund the guaranteed benefits of the plan. For 34 chemical companies surveyed for this part of the study, unfunded vested liabilities averaged 4.5% of net worth. This is the same percentage as Johnson & Higgins found in 1978. For all manufacturing, unfunded vested liabilities as a percentage of net worth was 7.3% in 1979 compared to 7.6% in the previous year.

No chemical company surveyed had unfunded vested liabilities greater than 20%, let alone the 30% legislated number, according to the survey. This is a much better perfor-



Source: Johnson & Higgins

mance than that for total manufacturing, where 9% of the companies had liabilities greater than 20%, and 5% of the firms had liabilities greater than 30% in 1979. In 1978, 11% of the companies had unfunded vested liabilities greater than 20%, with 6% having liabilities greater than 30%.

On the other hand, 29% of the chemical companies surveyed in 1979 had no unfunded vested liabilities in 1979, compared to 28% in 1978. For all manufacturing in 1979, 28% had no unfunded vested liabilities in 1979 compared to 25% in 1978.

In a separate survey of pension plans among 40 chemical companies, Price Waterhouse, the accounting firm, found that 21 or 52.5% of the chemical companies that it surveyed had no unfunded vested liabilities. Unlike the Johnson & Higgins survey, the Price Waterhouse study disclosed the percentage at each company. Price Waterhouse finds that of the chemical companies that it studied, Du Pont has the greatest unfunded vested liabilities as a percentage of net worth at 14.8%. This is followed by PPG Industries at 9.6%.

Yet another new pension plan study specifically for chemical companies is the ACS report, "Summary of Retirement Benefits" (C&EN, Dec. 8, page 66). It is concerned more with specific plan provisions rather than the financial standing of plans.

The strength of funding of pensions is shown in another way by the Johnson & Higgins study. The insurance firm says that pension plan assets as a percentage of total vested and nonvested past service liabilities is generally in good shape. For manufacturing as a whole, average plan assets equaled about 69% of average total past service liabilities in 1979. The percentage was the same for the chemical companies studied. Of the total manufacturing firms surveyed, however, 19% had plan assets equal to less than 50% of past service liabilities. For the chemical companies studied, only 5% had plan assets equal to less than 50% of total past service liabilities.

Johnson & Higgins concludes that the statistics that it has drawn up "point up the undeniable truth that most large corporate pension plans are, on average, well funded, that they are not a huge drain on corporate profits, and that they will be able to pay promised benefits." □

Specialty firm starts up "production lab"

A $1.5 million, 7500-sq-ft "production laboratory" has been opened at Danvers, Mass., by Alfa Products, a unit of Thiokol Corp.'s Ventron division. The laboratorylike facility triples Alfa's capacity to produce specialty and laboratory chemicals, according to general manager Roger S. Locke, and permits further expansion in organic chemicals. Alfa's former "production laboratory" at Beverly, Mass., will be taken over by other specialty chemical units of Ventron after renovation.

Alfa currently repackages and synthesizes about 7000 organic and inorganic chemicals and pure elements for laboratory use, specialty chemical manufacture, and electronic circuit fabrication. The firm also is distributor for ultrapure compounds, elements, and fabricated metals of Johnson Matthey Chemicals (Royston, England) and ion exchange resin products of Rohm & Haas. Alfa makes about 300 of the 6000 organic chemicals it sells and almost all of the 1000 or so inorganic chemicals.

Locke will not reveal Alfa's sales but notes that sales have grown about 25% yearly for the past five years. He ascribes this strong growth to having established the company in such specialized areas as organophosphorus compounds. Other factors include an increasing tendency for scientists and firms to buy rather than make needed chemicals, and the influence of chemical waste disposal regulations, which lead customers to buy only the small amounts actually needed.

Alfa will use the expanded space of the new Danvers facility to increase the number of organic compounds it makes. New organic candidates for synthesis will come both from scanning of chemical literature by Alfa research chemists and from the firm's continual re-evaluation of availability and prices from other suppliers.

In addition to bench-top space, the Danvers plant is equipped with 50 walk-in hoods, each fitted with a fire-suppressant system. Even sinks at ends of benches are enclosed in hoods. Technical manager Stephen A. Fine emphasizes that hoods are used as safety backup, and that minimal amounts of vapor are vented to the outside air. Alfa contracts with a disposal firm to cart away coproduced wastes. The facility has no storage capacity for solvents or starting materials. These will be brought several hundred yards from Alfa's warehouse elsewhere on the property in amounts actually needed.

Alfa also has a semiworks facility at the site capable of custom synthesis of organic chemicals in amounts up to 500 lb. □

CHECKOFF

NEW PLANTS

■ **Industrial gases.** Amerigas Inc., subsidiary of UGI Corp., plans to build 100 ton-per-day air separation plant in Dickinson, N.D. First stage, to cost $1.8 million, will be completed in 12 months with capacity of 35 tons per day of liquid nitrogen for use by oil and gas producers in Williston Basin area; second stage, to cost $1.5 million, will raise nitrogen capacity to 65 tons per day and oxygen to 35 tons per day. In another project, Amerigas plans to build 120 ton-per-day liquid carbon dioxide plant in Billings, Mont. Completion date set for August 1981; cost to be $2.6 million.

Union Carbide's Linde division plans to build two air separation plants producing oxygen, nitrogen, and argon. At Garland, Tex., combined 180 ton-per-day unit will bring total capacity there to 470 tons per day; scheduled to start up in first-quarter 1982. Second plant near Denver will have initial capacity of 350 tons per day. To cost $15 million, plant slated to start up in 1982.

■ **Iodine.** Calabrian International Corp. plans to build 3 million lb-per-year plant at undisclosed location, based on technology of Ise Chemical Industries of Japan. On completion in 1982, plant will make company a producer as well as marketer of element, which is expected to find increasing use in catalysts for production of synfuels and chemicals from synthetic gas.

PLANTS COMPLETED

■ **Carbon dioxide.** Airco has put on stream $4 million plant in Cherokee, Ala., with capacity of 300 tons per day.

■ **Mineral oils.** Witco Chemical has expanded capacities of its plants in Gretna, La., and Petrolia, Pa., 25% each and added 25% to petroleum sulfonates capacity at Gretna at cost of $4 million.

■ **Neopentyl glycol.** Badische's plant at Freeport, Tex., with annual capacity of 25 million lb has started up; capacity may be expanded later to 35 million lb.

OECD report cites growing East-West technology gap

Main direction of technology flow is from West to East; biggest and fastest growing item for lagging East is turnkey arrangements

Winston Churchill once described the Soviet Union as "a riddle wrapped in a mystery inside an enigma." If that's the Soviet Union, then the process of East-West technology transfer is a paradox entwined in a gamble buttressed by hope. For while the CIA and KGB agents plot their daily ruses, and while the Soviet and U.S. military machines stage their computerized Armageddons, the business of buying, selling, and lending cruises blithely on.

Blithely? Well, not quite. There's Poland to consider; and Afghanistan. But most of all there's the related fear in the banks of the West that heightening tensions between East and West could threaten already unstable international finances. Banks in the U.S., West Germany, France, and other western countries have lent the communist countries about $70 billion so far and tremble at the prospect of default.

Thus, while the communist world needs western technology to stay modern, western banks need their money back, making this new interdependence rather staggering at least and fascinating at most.

Western banks based in Moscow do a brisk business, even—probably especially—during periods of tension. Soviet technological ministries seek western outlets for their products and raw materials. Millions of dollars worth of business is transacted daily. Is the West, in the words of Lenin, selling the U.S.S.R. the rope to hang capitalism with? Or is trade the vehicle by which the Soviets will turn capitalist?

Time's roll of the dice will, of course, settle all that. But for those interested in the ins and outs of East-West technology transfer, time will be well spent perusing a new report on the field issued by the Organization for Economic Cooperation & Development, "Technology Transfer Between East and West." It was written by Eugene Zaleski and Helgard Wienert, sells for a hefty $50, and is a trove of statistics running through 1977.

"The direction of technology flows is mainly from West to East," says the report. "Between 1971 and 1974, 'technology-intensive' products accounted, on average, for 46% of all Eastern Europe's imports from the West but only 15% of exports in the opposite direction. The gap has widened further during recent years, the corresponding averages for the period 1976–77 being 49% and 12%."

For those looking for perceptual scoops, none are to be found in the study. But as a primer, scholarly synthesis, and source of collected data, the report is a must on any international trade and security bookshelf. The authors took years to do their homework, warming up by participating in OECD's monumental 1969 study of Soviet science policy.

As the authors point out, East-West technology transfer strikes a very simple profile. Western corporations sell to the Soviet Union and Eastern European countries because of profit and access to Soviet raw materials and future markets. The U.S.S.R. and its satellites buy western technology because, with the exception of technologically strong Czechoslovakia, they are know-how poor and generally lacking in innovative magic.

Moreover—and this is the key to Soviet motives—science and technology are the major instruments of communist-style social evolution. A Soviet report in 1977 put it this way: "Soviet economic activity . . . aims to include the country in a more active international division of labor and toward the resolution of such actual problems as developing long-term industrial cooperation between East

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and West and participation of socialist countries in the solution of world energy and raw materials problems."

The major methods of technology transfer are cooperative research and development programs, turnkey arrangements, licensing contracts, barter, and buy-back deals (in which eastern countries pay the West back in products rather than cash). But the biggest tickets in technology transfer are the turnkey arrangements. Contracts in the early 1970's averaged between $30 million and $50 million apiece. But they are much bigger now. In 1976, the latest date for which figures are accurately available, five such contracts were worth $900 million to $1.5 billion.

And short of open hostilities between the U.S.S.R. and western interests, these deals figure to get bigger and more extensive. The report cites such deals that were being negotiated in 1978 as a $1 billion to $2 billion contract for pulp and paper plants, a $3 billion contract for development of gas fields in Siberia, a $2.8 billion petrochemical project, and a $1 billion to $2 billion iron and steel complex.

"The Soviet Union's preference for turnkey plant purchases," says the report, "is clear from the fact that 90 out of 160 industrial cooperation agreements concluded with the West until 1975 were for the supply of turnkey plants."

There is clear-headed Soviet strategy behind this preference. Soviet chemical technology, for example, is believed to be up to 30 years behind the West's. Turnkey plants allow the Soviets to leapfrog over that gap, just as war-ravaged Japan and West Germany did during their industrial recovery programs in the 1950's. By the 1960's their technology was even with that of the U.S.

But the Soviet fear, as the report points out, is that dependence on western technology also means adoption of western-style management techniques and their flexible, democratic nature. They squabble among themselves over the danger western technology and ideas pose to Soviet purity. But for the time being, expedience is winning out because western technology offers shortcuts to economic development and efficient use of energy resources that by virtue of distance are scarce in the Soviet Union.

Although acknowledging the substantial gap between western and Soviet technology, the authors say the West should not be too smug. Soviet technologists are not dummies and they believe moreover that evolution is on their side. Capitalism's dying throes, they believe, is by necessity accompanied by fantastic technology, and they want it.

"In several sectors, such as high-voltage power transmission, numerically controlled machine tools, jet engines, etc., Soviet performance is quite remarkable," the report says. "And even if Soviet products do not achieve the same standards as those of the West . . . results achieved could well have considerable effects on national competitiveness." □

West shows little dependence on communist exports

	Communist country exports to West as % of world exports to West				
	1977	1976	1975	1974	1973
Textile fibers	11.6%	10.1%	10.5%	9.3%	9.1%
Chemical elements and compounds (organic and inorganic chemicals)	5.1	3.9	3.9	4.0	3.5
Manufactured fertilizer	6.9	8.0	7.7	6.6	9.1
Plastic materials	0.1	0.7	0.6	0.6	0.7
Chemical materials, nes[a]	2.1	2.2	2.6	3.9	3.3
Manufactures of metal, nes[a]	1.7	1.7	1.7	1.8	1.8
Electrical equipment and electronic products	1.3	1.3	1.3	1.3	1.6
Transport equipment	1.1	1.2	1.0	1.5	1.3
Total for all moderately sensitive sectors	2.3	2.1	2.1	2.2	2.3
HIGHLY SENSITIVE SECTORS					
Textile yarns and fabric products	4.2	4.4	4.2	4.0	3.7
Iron and steel products	3.6	3.6	3.0	3.2	4.1
Clothing	7.3	7.4	7.9	8.3	7.7
Footwear	5.3	5.4	5.6	5.2	5.1
TOTAL	**3.1%**	**3.0%**	**3.0%**	**3.0%**	**3.1%**

a Not elsewhere specified.

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Congress approves 12% rise in R&D funding

R&D funding for fiscal 1981 totals $31.4 billion, only 1% less than the Administration requested; DOD programs receive biggest boost

Budget-cutting fever was supposedly rampant in the last session of the 96th Congress, but that can't be proved by examining the totals contained in the fiscal 1981 R&D funding bills that Congress finally enacted only two and a half months after the fiscal year began.

Total R&D funding is a scant 1% less than the Administration requested and, at $31.4 billion, represents an increase of 12% over fiscal 1980 appropriations. While all are getting an increase, some agencies, as usual, did better than others. But unless the incoming Administration does a very good job of getting the economy under control, only the Defense Department can expect to keep well ahead of inflation. The other R&D agencies will continue to fall behind.

Congress did quite well by DOD, setting its fiscal 1981 R&D budget at just over $16 billion, an increase of 19%. That total includes such big-ticket items as $1.5 billion for the MX missile, $300 million for a new strategic bomber, $246 million for the space shuttle, and $65 million for the Trident II missile.

DOD's basic research programs received a 15% increase to $576 million. The Navy's defense research sciences program is up 14% to $225 million; that of the Air Force up 14% to $125 million; the Army's up 10% to $125 million; and the Defense agencies up 26% to $101 million. Although funding for basic research was increased substantially, it was increased by less than each service wanted, except in the case of the defense agencies.

The Department of Agriculture got the next biggest R&D budget increase, up 10% to about $620 million, actually 3% higher than requested. USDA's agricultural research budget presents a good example of just how involved Congress' Appropriations committees can get in deciding how much money should be spent on what. The budget earmarks $1 million for research on the effects of the Mount St. Helens eruptions on agriculture, $25,000 for sugarbeet disease research, and $30,000 for pickle research. It also includes nearly $157 million for basic agricultural research and $500,000 for research on guayule.

USDA's cooperative research budget of $186 million contains $17 million for special research grants, $16 million for competitive research grants, and $10.7 million for cooperative forestry research.

Next comes the National Science Foundation whose overall budget is up 8% to $1.1 billion, while its research and related activities budget is rising 9% to nearly $988 million.

The budgets for five of NSF's research programs were set at the amount requested. That means that funding for mathematical and physical sciences increases 15% to about $260 million; astronomical, atmospheric, earth, and ocean sciences 9% to $236 million; biological, behavioral, and social sciences 7% to $178 million; Antarctic programs 9% to $60.4 million, although most of the increase is earmarked for keeping up with rising fuel costs; and the ocean drilling program 13% to $22 million.

At press time House-Senate conferees had reached agreement on a continuing resolution that provides funds for agencies for which no appropriations bill was passed, a cate-

Congress gives federal R&D agencies less than they wanted but still allows 12% budget rise

$ Millions	1981 Final appropriations	1981 Budget request	1981 Change from request	1980 appropriations	% change 1980–81
Defense	**$16,018.7**	**$16,475.6**	**−3%**	**$13,412.1**	**19%**
Air Force	6,774.0	7,033.4	4	4,941.9	37
Navy	4,861.2	4,862.9	−0.1	4,537.4	7
Army	3,086.8	3,234.5	−5	2,853.3	8
Defense agencies	1,254.6	1,302.7	−4	1,037.0	21
Director test and evaluation	42.1	42.1	0	42.5	−1
NASA	**5,541.2**	**5,517.6**	**0.4**	**5,244.8**	**6**
R&D	4,396.2	4,364.5	0.7	4,092.5	7
Research and program management	1,030.0	1,033.2	−0.4	996.2	3
Facilities	115.0	120.0	−4	156.1	−26
NIH	**3,686.4**	**3,490.4**	**6**	**3,429.4**	**8**
Energy	**3,358.1**	**3,314.2**	**1**	**3,320.0**	**1**
Energy supply R&D	2,268.7	2,249.9	0.8	2,245.1	1
Fossil energy R&D	711.4	687.6	3	733.0	−3
General science and research	378.0	376.7	0.3	341.9	10
NSF	**1,076.1**	**1,074.0**	**0.2**	**991.8**	**8**
Research and related activities	987.9	992.8	0.5	904.1	9
Science education	83.2	75.7	10	82.2	−2
Science activities overseas	5.0	5.5	−9	5.5	−10
Commerce	**872.5**	**877.8**	**−0.6**	**821.6**	**6**
NOAA	759.4	751.7	1	722.4	5
Science and technical research	11.31	121.1	−7	99.2	14
USDA	**620.4**	**600.5**	**3**	**566.8**	**10**
Agricultural research	414.4	399.8	4	373.3	11
Cooperative research	201.0	195.1	3	189.0	6
Science activities overseas	5.0	5.6	−11	4.5	11
EPA R&D	**253.5**	**270.4**	**−6**	**237.6**	**7**
TOTAL	**$31,426.9**	**$31,620.5**	**−1%**	**$28,024.1**	**12%**

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Dr. Annette T. Rosenblum
Department of Public Affairs
American Chemical Society
1155—16th St., N.W.
Washington, D.C. 20036

Applications consist of a letter of intent, resume, and two letters of reference. The letter of intent should include a description of the applicant's experience in public-oriented projects in which scientific or technical knowledge was used as a basis for interaction and a statement that tells why they have applied for the Fellowship and what they hope to accomplish as an ACS Congressional Fellow. The resume should describe the candidate's education and professional experience and include other pertinent personal information. Letters of reference should be solicited from people who can discuss not only the candidate's competence but also the applicant's experience in public-oriented projects. Arrangements should be made to send the letters of reference directly to ACS.

For further information call (202) 872-4383.

gory in which the National Institutes of Health fell. Under the agreement NIH's budget will also be up 8% to $3.7 billion, about 6% more than the Administration requested.

The Environmental Protection Agency had wanted a 13%, or $32.8 million, increase for its R&D programs. Congress gave the agency a 7% increase to $254 million. That amount includes $8.4 million for acid rain research, $2.6 million for Great Lakes research, $1.9 million for groundwater research, and $900,000 for cold climate research. The House had directed that the $12.2 million shortfall from the budget request come out of the agency's anticipatory research programs, but in the end, Congress left it up to the EPA administrator to decide which programs would not get increases.

The National Aeronautics & Space Administration's R&D budget also will be up 7% to $4.4 billion. (Its overall budget will be up 6% to $5.2 billion.) Congress took the unusual action of setting definite spending ceilings for nine NASA programs, including the space shuttle, the spacelab, and the gamma ray observatory, because of the major cost overrun problems these programs are experiencing. It directed NASA to contract with the National Academy of Engineering and the National Academy of Sciences to provide the agency with ongoing, independent project review. Congress said it would approve no major program changes proposed by NASA unless an NAE panel concurred with those changes.

Meanwhile, at the Commerce Department, the National Oceanic & Atmospheric Administration's budget is up 5%, slightly more than requested, to $759 million. The science and technical research budget, which covers the National Bureau of Standards and the National Technical Information Service, among others, is up 14% to $113 million.

For the Department of Energy, which used to see its R&D budget rise by leaps and bounds, Congress has approved an increase of only 1% to $3.4 billion. The big loser is nuclear fission where the budget has been cut 18% to about $675 million, but fossil energy R&D is also down 3% to $733 million.

Among the winners are solar, for which the budget is up 21% to $557 million, and basic energy research, whose budget is up 12% to $244 million. Within that category, funding for material sciences is up 12.5% to $87.7 million and funding for the chemical sciences is up 11.4% to $60.7 million. In addition, university research support is up 15% to $7.8 million. □

Federal Alert—*new regulations*

This listing covers noteworthy regulations appearing in the Federal Register *from Nov. 10 to Dec. 5. Page numbers refer to those issues.*

PROPOSED

Environmental Protection Agency—Proposes standard methods for determining data on substances tested under Toxic Substances Control Act; comments by Jan. 21, 1981 (Nov. 21, page 77332).

Proposes to withdraw ammonia from list of chemicals considered toxic pollutants; effective Dec. 1 (Dec. 1, page 79692).

Occupational Safety & Health Administration—Proposes regulation of occupational exposure to pesticides during manufacture or formulation processes; comments by Jan. 31, 1981 (Dec. 2, page 80078).

FINAL

Environmental Protection Agency—Sets particulate emissions standards for ammonium sulfate manufacturing plants; effective Nov. 12 (Nov. 12, page 74846).

Establishes list of 80 hazardous waste streams from chemical plants, with reasons why they are hazardous, as required by Resources Conservation & Recovery Act, effective Nov. 19 (Nov. 12, page 74884).

Promulgates rules that will prevent impairment to or improve the visibility of U.S. wilderness areas; effective Jan. 2, 1981 (Dec. 2, page 80084).

Establishes interim rule designating wastes generated in pipelines as not being hazardous wastes under RCRA until they are removed from the pipeline; effective Nov. 19 (Dec. 4, page 80286).

Nuclear Regulatory Commission—Establishes rules to cover specific licensing requirements for storage of spent nuclear fuel in independent fuel storage facilities; effective Nov. 28 (Nov. 12, page 74693).

NOTICES

U.S. Regulatory Council—Publishes Calendar of Federal Regulations; contains summary of upcoming important federal regulations (Nov. 24, page 77702).

Environmental Protection Agency—Requests comments on two reports on factors affecting uptake of cadmium by food plants grown in soil treated with cadmium-containing wastes; comments by Jan. 2, 1981 (Nov. 18, page 76147).

Offers groundwater protection strategy to protect and gather information on U.S. groundwater; comments by Feb. 18, 1981 (Nov. 24, page 77514).

Announces availability of water quality criteria documents for all 64 priority toxic pollutants as required by Clean Water Act (Nov. 28, page 79318).

Announces availability of draft document to support upcoming regulation on used-oil disposal and recycling; comments by Jan. 19, 1981 (Dec. 5, page 80561).

WORLD

The world chemical economy is entering the new year on shaky legs. Throughout the industrialized countries, demand is slack, raw material costs are spiraling upward, and profits are under pressure.

The U.S. chemical industry, for example, is pulling itself from the depths into which it fell after new orders dried up last spring. But in several key markets, the outlook for growth now is far from robust.

In Western Europe, chemical producers confront an onslaught of problems. Business is slumping. Capacity is excessive. Imports are flooding their markets. Even in the controlled economies of Eastern Europe, ambitious expansion plans for chemicals are falling short and investment is being trimmed.

Japan's chemical firms likewise face reduced demand in their home markets. At the same time, they are struggling hard to hold onto their important customers for exports against rising outside competition. On the other hand, exports are one bright spot for an otherwise sluggish Canadian chemical business. Rich hydrocarbon resources are making Canada a force to be reckoned with in the world chemical market.

Other areas with ample resources—in Latin America and the Middle East—also are bidding for their share of those markets with heavy investments in big new chemical complexes. China, too, is building an industrial base that in time may make it a world contender. All this points to a much more competitive chemical economy at a time when the world's ability to absorb expanding output is in doubt.

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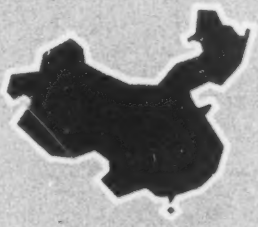

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A shaky recovery for chemical producers

Business is picking up from last spring's slump, but slack demand from key markets may limit growth during the year ahead

David M. Kiefer, C&EN Washington

This year's recession arrived just about on the schedule economic analysts had set for it a year ago. Economic indicators were definitely on the downswing just after 1980 began. The decline had accelerated by midspring, as interest rates soared to record high levels. But the slump was relatively short. Interest rates declined sharply. Even inflation seemed to be cooling off a bit. By midsummer, the business cycle hit bottom, and the past five months or so have witnessed a steady improvement.

Thus, the year ends with neither a bang nor a whimper. Industrial production is close to the same level as when the year began. It's been a standoff year, as it were, with real (adjusted for inflation) gross national product for the year as a whole down a modest 0.5 to 1% from 1979 and total industrial production averaging about 4% lower.

So far, so good. But by now, according to the economic scenarios being publicized early in the year, the recovery phase of the business cycle should be in full swing and the U.S. economy winging off into a healthy prosperity. It isn't working out that way, though. In fact, economic prospects are unusually clouded for a period so early in a cyclical upswing. Inflation remains uncontrolled. Interest rates are soaring again. The prime rate that the nation's banks charge their biggest and best business customers, which had plummeted from a record 20% last April to just under 11% by midsummer, has spiraled up to record levels again. Mortgage rates also have moved into the stratospheric heights of last spring. Car sales early in the new model year are distinctly disappointing to the auto industry.

All in all, what has been one of the shortest recessions on record now may be followed by one of the shortest recoveries, many business analysts are warning. Even if the high cost of borrowed money does not catapult the economy into another recession, as it did last winter, economists now are forecasting very slow growth for the U.S. economy at best for the year ahead. The 11 eminent economists who make up the Conference Board's economic forum, for example, look for "a stagnant economy . . . into early 1981 and only a mild upturn later in the year." Their consensus is that real GNP will grow little more than 1%, with industrial production up less than 2%, for the year as a whole. Unemployment will rise, hovering at just under 8% of the labor force for most of the year. But inflation will moderate only a little, with consumer prices and producer prices averaging about 11% higher; both are estimated to have risen 13.5% this year.

None of this bodes well for the U.S. chemical industry, of course. The industry has pretty well tracked the overall economy during the past 12 months. Business was relatively strong last winter. With production at record highs and selling prices up strongly (prices of industrial chemicals, on the average, during the first quarter of 1980 were nearly 30% above what they had been a year earlier), chemical producers chalked up strong sales and profits early in the year. Customers were stocking up in anticipation of still higher prices. And business in overseas markets, especially Europe, was particularly good; the combination of relatively low-cost feedstocks for U.S.-made petrochemicals and a relatively weak U.S. dollar on foreign exchange markets caused U.S.-made chemicals to be one of the best bargains going for foreign buyers.

But the year's fast start also was short-lived. Domestic demand dried up in April and May. By July, production of industrial chemicals and synthetic materials (plastics, fibers, and synthetic rubber) had collapsed 22% in just six months. The dollar volume of sales remained high, thanks to higher prices—although with demand stagnant, prices of chemicals in general rose little, if at all, this past summer and autumn. And earnings skidded for most major producers of chemical commodities. In the third quarter, earnings in the basic chemical industry were about 20% lower than in the like period of 1979.

Business has been picking up steadily since last summer, however, with output now probably running at rates close to those of last winter. But for the year as a whole, C&EN estimates, production of chemicals and synthetics probably was 4 to 5% lower than in 1979, and though producers of these products boosted their sales an estimated 7%, their profits probably fell about 10%.

Several of the basic petrochemical intermediates were especially hard hit. Output of such major products as acetic acid, butadiene, cumene, cyclohexane, phenol, and styrene probably trailed 1979's total 10 to 20%. Production declined 5 to 10%, too, for such big-volume plastics as polyethylene, polystyrene, and polyvinyl chloride. Among synthetic fibers, nylon in particular took it on the chin.

The year has not been a downer throughout the broad chemicals and allied products industry, however. Agricultural chemicals, both fertilizers and pesticides, have done comparatively well. W. R. Grace, for one, expects to about double its operating earnings from fertilizer materials (to $65 million or $70 million) this year,

and other fertilizer makers also have racked up higher profits throughout 1980. Output will be up, too, for such big-volume inorganic chemicals as ammonia, phosphoric acid, and sulfuric acid, whose fortunes are largely tied to fertilizer demand.

Earnings are higher, too, this year for several firms whose business focuses on specialty chemicals, such as Lubrizol, Nalco Chemical, and Mallinckrodt. And the pharmaceutical segment of the overall industry, typically recession-resistant, has swung through 1980 largely unscathed. All in all, earnings of drug makers are likely to be up 15 to 20% this year, on a slightly smaller advance in sales.

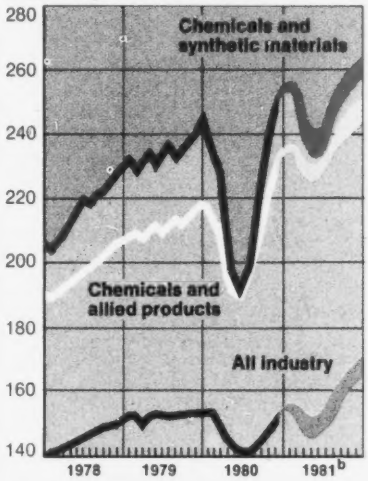
Overall, then, production in the chemicals and allied products industry probably will be only 2 to 3% lower than last year. And profits are likely to be 4 to 5% higher, as gains by drug firms and makers of specialty chemicals more than balance lower profits for producers of industrial chemicals and synthetic materials.

The outlook for chemical producers next year hinges to a large degree on several key markets that at present are being severely buffeted by tight credit and rising prices.

One of these is the automobile industry. This has not been a robust year for U.S. auto makers. Sales will total about 9 million autos, 16% fewer than last year. However, a quarter of these have been imports, and sales of U.S.-made autos have slumped more than 20% to 6.6 million. Sales now are a bit higher than they were earlier in the year, but the 1981 models have not attracted the number of customers that Detroit had counted on. Consequently, production schedules have been trimmed. Production last month was the lowest for any November since 1970, and it will stay relatively low this month as well. As a result, total U.S. output for 1980 will come in at only about 6.4 million to 6.5 million cars, the fewest since 1961 and 23 to 24% under last year's output. Truck production has been even more severely depressed; this year's

Production will rise after slow start next year...

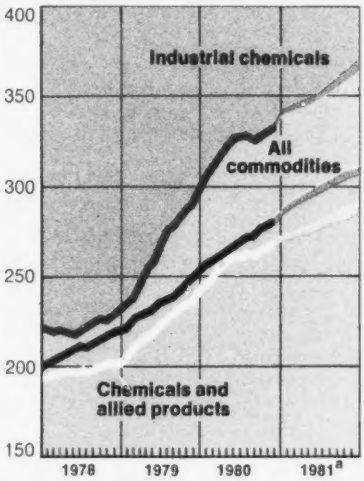
Industrial production,[a] 1967 = 100



a Seasonally adjusted. b C&EN estimate.
Source: Federal Reserve Board

...while selling prices continue their sharp rise...

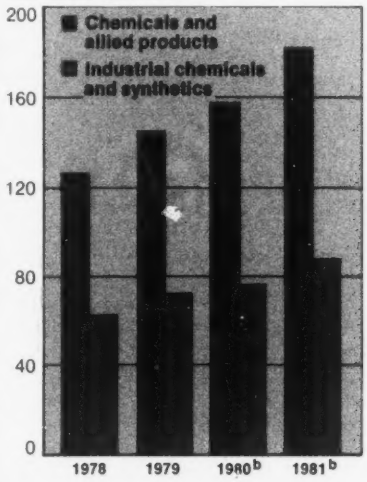
Producer price index, 1967 = 100



a C&EN estimates.
Source: Bureau of Labor Statistics

...pushing chemical firms' sales up again...

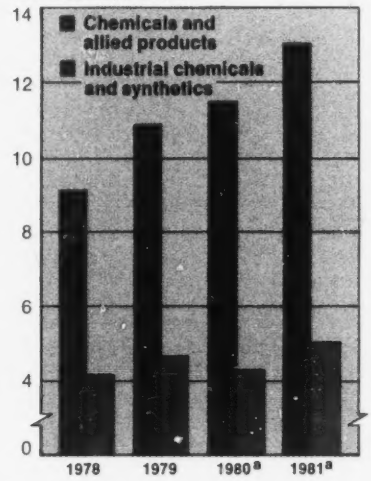
Net sales,[a] $ billions



a Excludes sales of foreign subsidiaries. b C&EN estimates. **Source:** Federal Trade Commission

...and restoring some luster to their profits

Net income, $ billions



a C&EN estimates.
Source: Federal Trade Commission

Organic chemicals, hard hit by this year's slump in production, will recover next year

	1978	1979	1980	1981
INORGANIC CHEMICALS (Thousands of tons unless otherwise noted)				
Ammonia	17,119	18,523	19,200	21,200
Chlorine gas	11,052	12,228	11,600	12,400
Hydrochloric acid	2,793	3,090	2,950	3,075
Nitric acid	7,934	8,465	8,800	9,200
Oxygen, billions of cu ft	430	457	440	465
Phosphoric acid	9,637	10,317	11,000	11,550
Sodium hydroxide	11,309	12,772	11,900	12,700
Sulfuric acid	41,314	43,118	44,700	46,000
ORGANIC CHEMICALS (Millions of lb unless otherwise noted)				
Acetic acid	2,776	3,265	2,750	3,050
Acetone	2,519	2,653	2,280	2,450
Acrylonitrile	1,752	2,018	1,800	1,950
Benzene, millions of gal	1,488	1,672	1,540	1,650
Butadiene	3,515	3,583	2,940	3,450
Cumene	3,380	3,917	3,200	3,550
Cyclohexane	2,332	2,425	2,000	2,200
Ethylene	25,955	29,904	28,300	31,300
Ethylene glycol	3,904	4,729	4,600	4,900
Formaldehyde	6,381	5,971	5,300	5,700
Methanol	6,443	7,367	7,150	7,600
Phenol	2,682	2,981	2,550	2,800
Phthalic anhydride	978	1,013	830	975
Propylene	13,014	14,198	13,500	14,900
Styrene	7,186	7,484	6,650	7,200
Toluene, millions of gal	1,054	1,010	960	1,050
***o*-Xylene**	1,013	1,082	1,020	1,100
***p*-Xylene**	3,516	4,650	4,100	4,350
PLASTICS (Millions of lb)				
Polyethylene, high-density	4,201	5,010	4,500	5,200
Polyethylene, low-density	7,111	7,793	7,300	8,050
Polypropylene	3,074	3,840	3,650	4,200
Polystyrene	3,823	4,005	3,600	4,000
Polyvinyl chloride	5,723	6,119	5,450	6,000
SYNTHETIC FIBERS (Millions of lb)				
Acrylic and modacrylic	726	761	790	820
Nylon	2,550	2,720	2,325	2,450
Olefin and vinyon	692	759	760	800
Polyester	3,800	4,178	3,950	4,150

Sources: Bureau of the Census, International Trade Commission, Society of the Plastics Industry, Textile Economics Bureau, C&EN estimates (for 1980 and 1981)

1.6 million units will be little more than half the number turned out in 1979.

Next year is bound to see some improvement for the auto industry. Current forecasts peg auto sales at somewhere between 10 million and 11 million, with most of them clustered around the lower end of that range. At that level, only about 7.3 million to 7.5 million cars are likely to roll off U.S. assembly lines, a small gain from this year but still far below the more than 9 million vehicles assembled in both 1977 and 1978.

The closely related tire market is similarly depressed. Output, off 25 to 30% this year, is not expected to recover more than 10% in 1981.

Construction is another major market for chemicals that has faltered badly this year—and that also shows little promise for much of a comeback during the 12 months ahead. Housing starts have been rising unsteadily from the low annual rate of just 906,000 that they had sagged to last May. But starts of new housing this year now are expected to total only about 1.2 million, down from 1.75 million last year and about 2 million in both 1977 and 1978. (Economists estimate that the U.S. needs about 2 million new housing units a year to meet normal demand.)

Next year probably will bring some recovery to the depressed housing business, but rising prices and high mortgage interest rates severely limit short-term prospects—and probably will cause another decline early in the new year. For the year as a whole, builders are figuring that only some 1.4 million to 1.6 million new housing units will be started, despite the pentup housing demand stemming from reduced building activity this year and last. Meanwhile, nonresidential building, also in a slump this year, is expected to be lower again in 1981, in volume if not in inflated dollar amounts.

Hard times for new housing has put a crimp in still another important outlet for chemicals: furniture, appliances, and other home durable goods. Sales of such items are down 4 to 5% this year, after adjustment for inflation, and real growth is likely to be slim during the next 12 months.

In addition, U.S. chemical producers will be hard-pressed to expand export sales as they have during the past two years. The dollar volume of U.S. chemicals sent overseas was up an estimated 21% to $21 billion this year alone. Exports to the less developed world probably will remain buoyant next year. But with recession deepening elsewhere in the industrialized world and foreign producers demanding protection against low-cost U.S. chemicals, export markets are likely to be less of a prop for the U.S. chemical industry than they have been recently.

All this means that U.S. chemical firms have their work cut out for them in 1981. C&EN estimates that slack demand in such prime markets as autos and housing will undercut chemical production during the first half of the year, although not nearly to the extent that was experienced last spring. For the year as a whole, output of chemicals will average 8 to 10% higher this year. Even so, further growth between now and next December probably will be slim at best, perhaps a mere 2 to 4%.

Prices will be higher, also, as chemical producers strive to pass rising energy and feedstock costs along to their customers. But slow growth in several big markets will limit producers' pricing flexibility; prices of industrial chemicals, for example, are not likely to come close to repeating the more-than-20% increase registered this year—most of which occurred early in the year.

With output and prices rising, sales volume undoubtedly will be above this year's total, perhaps 15% or more. Profits, too, are expected to snap back for producers of industrial chemicals, despite a continuing cost/price squeeze. Whether they will make it all the way back to 1979 levels, however, depends on several big outlets for chemicals shaking themselves out of their current doldrums. □

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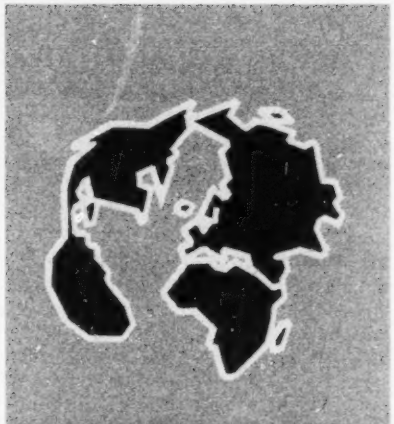


Economics favor U.S. trade in chemicals

U.S. chemicals continue to maintain a strong position in world markets, but trade disputes with Europe cloud the outlook

Earl V. Anderson, C&EN New York

U.S. auto makers are taking a beating from imports. About 25% of the cars sold in the country are made somewhere else.

Steel companies have felt sufficiently threatened by imports to consider antidumping action against seven European steel-producing countries. They settled, instead, for an improved "trigger price" mechanism (which in effect sets a floor price on imported steel) to deter steel imports.

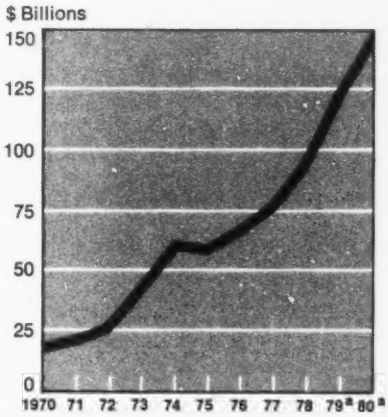
Textiles, electronics, and shoes are among other U.S. industries that are feeling the sting of imported products.

But what about chemicals? As far as U.S. foreign trade is concerned, chemicals are like a breath of fresh air in a smoke-filled room. For the eighth consecutive year, the chemical industry will chalk up a record excess of exports over imports.

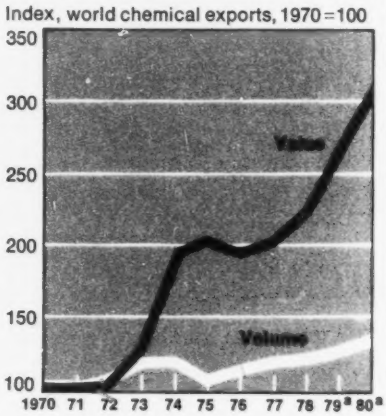
Chemical exports this year, in fact, will top $20 billion for the first time and come tantalizingly close to $21 billion. The significance of that figure comes more into focus by remembering that only three years ago, U.S. chemical exports first topped $10 billion. In those three years, they have grown at a rate of 25% annually. Last year and this year, the advances were 37% and 21%, respectively.

On the other side of the trade coin, chemical imports increased only 17.5% annually during the past three years to about $8.8 billion, giving the U.S. chemical industry a lopsided trade surplus of $12.2 billion.

World chemical exports are up 50% since 1978 . . .



. . . but more because of price than volume increases



a C&EN estimates. **Source:** United Nations

Obviously, the U.S. chemical industry is in excellent competitive health as far as international trade is concerned. One reason, as the industry's European counterparts are quick to point out, is its heralded "feedstock advantage." There's no doubt that government price controls on crude oil give U.S. petrochemical producers an edge on feedstock costs.

Although conceding that such an advantage may exist, U.S. companies note that its impact is overblown. William S. Sneath, Union Carbide's chairman of the board, argues that U.S. trading partners who pay for their energy supplies with weakened dollars are not quite at the disadvantage implied by the difference between U.S. and world energy prices.

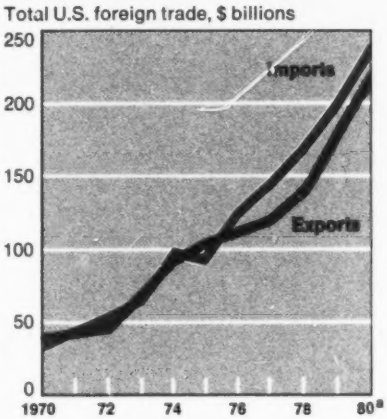
There are several other factors that explain the U.S. chemical industry's strength in the world marketplace. One is the weakened dollar that Sneath speaks of. It makes U.S. exports less expensive in overseas markets and, conversely, it makes imports more expensive in the U.S.

The U.S. also is the largest single integrated chemical market in the world. This has enabled U.S. chemical companies to build large plants that have an inherent economy of scale. Coupled with excellent technology and management, this economy of scale improves the industry's competitive strength.

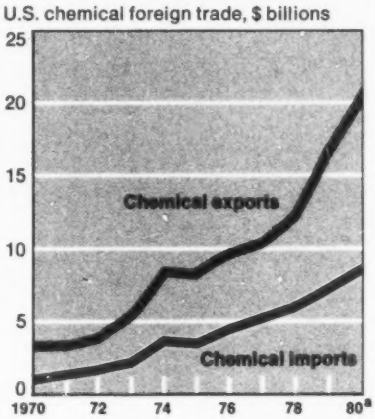
Perhaps even more important, say many industry analysts, is the feedstock flexibility available to U.S. plants. Unlike many European and Japanese producers, for instance, U.S. basic petrochemical producers aren't locked solely into naphtha as their feedstock. As prices dictate, they are able to switch to less expensive, lighter feedstocks, such as natural gas liquids.

This strength and flexibility have shown up in chemical export statistics during the past few years, which indicate that a trend that U.S. chemical

U.S. trade deficit continues to decline a bit this year . . .



. . . as chemical trade hits a healthy $12 billion surplus



a C&EN estimates. **Source:** Bureau of the Census

companies have fretted about earlier in the 1970's now has changed.

From 1970 until 1978, the U.S. share of the world chemical export market shrank from 18.6% to 14.1%. In the past two years, however, that share has started to expand slightly. This year, it probably will weigh in at 14.9%.

Assuming that the industry will continue to remain strong and flexible in its feedstock options, it likely will continue to fare well in the international market. Most industry trade experts are confident of this, even though it's inevitable that, with decontrol of petroleum prices, U.S. energy and feedstock costs will rise to world levels.

This optimism, however, doesn't mean that there aren't some storm clouds gathering on the trade horizon. Some of them are no further away than next year.

First is the distinct probability that world trade in general, and chemical trade in particular, will not register the sizable increases in 1981 that took place in the recent past. In the past three years, for instance, total world trade has increased 12%, 19%, and 14% on a value basis. This year, world trade of all products (measured as exports) will hit a whopping $1.76 trillion.

World chemical trade has grown at an even higher rate. This year, again measured as exports, it will reach $150 billion.

But the problem with dollar figures is that they contain an inflation factor that masks real growth On a volume basis, world chemical trade probably increased no more than 5% this year and a similar amount in 1979.

Next year, although the dollar value of world chemical trade may score a sizable increase, real growth may be limited to 2 to 3%. Growth will be stifled by the depressed economy in many of the world's industrialized nations. These countries, along with many developing nations that are blossoming into lucrative export markets for U.S. chemicals, also will be increasingly saddled with huge bills for imported oil.

To compensate, they will be cutting back on imports of other products. Protectionism already has reached worrisome proportions and no doubt will increase next year. As a result, the overseas market for U.S. chemicals isn't likely to grow so rapidly next year as it has in the past.

Meanwhile, a problem that has been brewing for the past two years may come to a head next year. European Economic Community officials may be forced to act to stem the flood of imported petrochemicals and synthetic fibers from the U.S.

For many U.S. chemical exporters, this is the biggest and most immediate problem. Little wonder. Collectively, the EEC countries represent the biggest single market for U.S. chemical exports. This year, fully 25% of all those exports will end up in EEC.

That's why the U.S.-EEC chemical trade dispute that some fear could blossom into a trade war is so important. It started with what British companies viewed as a flood of imported polyester and nylon fibers from the U.S. at prices they considered unfairly low. It has since spread to other EEC countries and to many other products.

The basic complaint, voiced by the European Council of Chemical Manufacturers' Federation (CEFIC) on behalf of its members, is that the U.S. has an unfair feedstock cost advantage as a result of price controls on its domestic petroleum. CEFIC has been urging EEC officials to take action against U.S. fiber and petrochemical exports to stem the flood.

So far, Britain has been allowed by EEC to set quotas on nylon and polyester yarn imported from the U.S. Italy and France believe that they should be eligible for similar protection. In Italy, a court has prohibited polyester imports from two U.S. companies.

Recently, the Commission of the European Communities imposed a provisional 10.6% antidumping duty on vinyl acetate monomer imported from the U.S. Three U.S. companies, however, are excluded from the action. Similar EEC antidumping action is pending on U.S. styrene exports. Meanwhile, complaints are piling up against U.S. exports of liquid fertilizers and xylenes. And CEFIC is preparing a complaint against U.S. phenol shipments to EEC.

Despite the quotas on fibers and the antidumping duty on vinyl acetate, CEFIC and it members think that EEC officials aren't taking the U.S. feedstock advantage seriously enough. They also think that EEC officials are not acting rapidly or strongly enough.

But EEC officials apparently are reluctant to move too far too rapidly

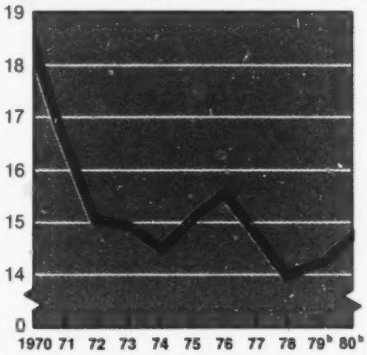
Developing countries loom larger as markets for U.S. chemicals

$ Millions	1980[a]	1979
U.S. CHEMICAL EXPORTS		
Canada	$ 2,120	$ 1,994
Western Europe	6,480	5,585
Eastern Europe	90	200
Japan	2,015	1,652
Communist Asia	350	125
Middle East	440	387
Rest of Asia	2,755	2,204
Latin America	5,000	3,814
Australasia	655	608
Africa	730	465
Other	365	272
Total	$21,000	$17,306
U.S. CHEMICAL IMPORTS		
Canada	$2,455	$2,362
Western Europe	4,180	3,449
Eastern Europe	165	107
Japan	725	616
Communist Asia	110	60
Middle East	55	48
Rest of Asia	175	148
Latin America	540	405
Australasia	175	158
Africa	80	49
Other	140	83
Total	$8,800	$7,485

a C&EN estimates. **Source:** Bureau of the Census

U.S. share of chemical exports edges higher again

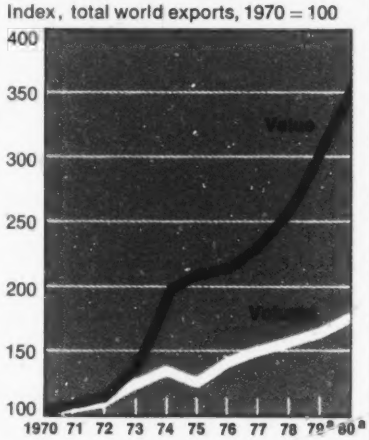
U.S. chemical exports, % of world total[a]



a Defined as: U.S. exports as per cent of world chemical exports less U.S. imports. b C&EN estimates. **Sources:** United Nations, Bureau of the Census

Value far outruns volume for total world exports

Index, total world exports, 1970 = 100



a C&EN estimates. **Source:** United Nations

in fear of starting a trade war with the U.S. Already, an antidumping complaint is in the works in the U.S. against imports of anhydrous sodium metasilicate from France. And the U.S. is certain to seek compensation for unjustified restraints that EEC slaps on U.S. exports. If it fails to get compensation, the U.S. will retaliate with restraints of its own.

What action EEC may be able to take under the rules of the General Agreement on Tariffs & Trade (GATT) still is unclear. GATT rules, for instance, do not prohibit price controls on energy or feedstock products. And they do not allow antidumping duties unless a domestic industry has been materially injured by underpriced imports.

EEC officials apparently are not yet convinced that the damage inflicted by imported U.S. petrochemicals has reached that stage. Even some European chemical company spokesmen admit that their troubles are not entirely the result of imports from the U.S.

It's no secret that many European chemical producers are burdened with excess capacity. Their profits have suffered by their cutting prices in an effort to hold market share.

Others have been slow to react to changing market conditions. Some, for instance, stuck too long with producing basic chemicals instead of developing more advanced, sophisticated products. And EEC companies are getting increased competition from Eastern Europe as products start flowing into Western Europe as payment for technology sold under barter deals.

Whatever the reasons, EEC chemical producers are hurting and the EEC-U.S. chemical trade conflict won't be easy to resolve. Earlier this month, EEC and CEFIC officials on a consulting and fact-finding mission met in Washington with their U.S. counterparts from government and industry. What will come out of the talks is difficult to predict. But whatever happens probably will happen early in 1981 and will have important repercussions for U.S. chemical exports.

The U.S.-EEC chemical trade imbroglio is by far the most pressing trade problem facing U.S. chemical trade experts. But it is not the only one.

Among other things, they are worried about how all of the nontariff barrier agreements reached during the Tokyo round of multilateral trade negotiations will be implemented. One way the industry's trade experts will be monitoring them will be through participation in restructured industry-to-government advisory committees. These committees functioned well during the negotiations themselves and there's no reason to believe that they won't continue to function well again.

One complication may be the restructuring process itself. This has been started under the Carter Administration. Whether changes will be made by the Reagan Administration remains to be seen. □

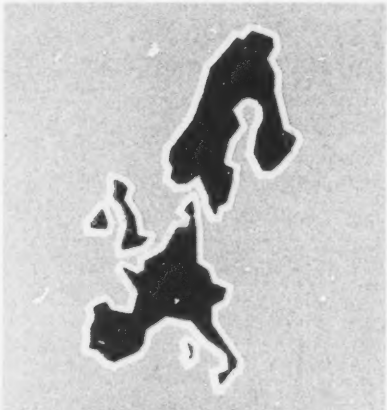
The cost of U.S. oil imports continues to soar . . .

U.S. petroleum imports	1980[a]	1979	1978	1977	1976	1975
All petroleum products						
Volume (millions of bbl)	2480	3031	2970	3183	2646	2186
Value ($ millions)	$74,810	$56,727	$39,526	$42,368	$32,226	$25,197
Unit value ($ per bbl)	$30.17	$18.72	$13.31	$13.31	$12.18	$11.53
Crude and partly refined petroleum						
Volume (millions of bbl)	2020	2480	2399	2540	2066	1661
Value ($ millions)	$62,555	$46,350	$32,232	$33,910	$25,653	$19,293
Unit value ($ per bbl)	$30.97	$18.69	$13.44	$13.35	$12.42	$11.62

. . . sinking the U.S. trade balance into a deep deficit

$ Millions						
Total U.S. exports	$222,000	$181,639	$143,575	$121,150	$114,807	$107,130
Fuels exports[b]	7,670	5,616	3,878	4,184	4,226	4,465
Total exports without fuels	**$214,330**	**$176,023**	**$139,697**	**$116,966**	**$110,581**	**$102,665**
Total U.S. imports	$242,000	$206,327	$172,026	$147,685	$120,677	$96,116
Fuels imports[b]	81,000	60,061	42,105	44,537	33,996	25,476
Total imports without fuels	**$161,000**	**$146,266**	**$129,921**	**$103,148**	**$86,681**	**$69,640**
Actual trade balance	−$20,000	−$24,688	−$28,451	−$26,535	−$5,870	−$11,014
Trade balance without fuels	$53,330	$29,757	$9,776	$13,818	$23,900	$33,025
Petroleum imports as % of total imports	30.9%	27.5%	23.0%	28.7%	26.7%	26.2%

a Full year, estimated from 10-month data. b Mineral fuels and related materials (SITC section 3). Exports are primarily coal. Difference between values of fuels imports and exports of "all petroleum products" is primarily the value of natural gas. **Source:** Bureau of the Census



Business decline deepens in Western Europe

Chemical firms, hit by weakening demand, falling prices, competition from imports, and overcapacity, face a depressing 1981

Dermot A. O'Sullivan, C&EN London

The chemical industry in Western Europe is ending this first year of the present decade with a distinct overhang of gloom. "Depressing" is one way to describe business this past year. Many chemical executives refer to the situation as "disastrous." Prospects for 1981 aren't encouraging.

"One of the most positive things that can be said about 1980 is that it took so long for the recession to hit us," comments Richard Hobbs, head of public affairs for Shell International Chemical in London. "Most companies at least had a good first quarter to bolster them through the awfulness. But we went off the cliff from about April onward. The decline went very fast into the third quarter. The rate of recession slowed in the fourth.

"Looking to 1981, I don't think we will see any improvement in the first and second quarters. My own judgment is that business conditions will remain very depressed until the end of the year. We might see a recovery in the fourth quarter if we're lucky. If that turns out to be the case, then chemical companies with accounts that span the calendar year will have another year in which there are three bad quarters and one that's reasonably supportive, although I don't expect next year's fourth quarter to be as good as this year's first quarter was."

Matthias Seefelder, BASF's chairman, might have been speaking for the entire chemical industry in Western Europe when he said recently, "The weak economic situation, increased imports, and movements in stocks have had a strongly suppressive influence on prices. This has led to the fact that our price index has dropped since early summer.

"Difficulty stemmed, too, from the more limited utilization of our plants, which led to a rise in unit production cost. Along with this, we had to cope with the drastic rise in price of raw materials. Both influences have had a markedly bad effect on our position compared with last year."

Last fall, and during the opening months of this year, users of plastics and petrochemical intermediates in particular were building up their inventories as a hedge against expected price increases. The result was a brisk level of business. But as 1980 progressed, they began cutting back on inventories and have been doing so since then.

The reduction in inventories couldn't have come at a worse time. It occurred around midyear or slightly before, compounding the usual slack summer pace of business in Europe.

"No one expected a downturn as severe as it turned out to be," admits Philip G. Harvey, a director at Imperial Chemical Industries headquarters in London. "In volume terms, the destocking was quite savage in the summer. And the European market, which is a very fragile and disorderly one at the best of times, collapsed. People who had been expecting sales volume drops of 10% or so were experiencing drops closer to 30%. As a result, they became convinced that competitors were taking their market shares, so they cut prices. And the price collapse was disastrous."

So it is that chemical companies registered a decisive dip in their earnings in the July-through-September period. Among the hardest hit

Profits slump sharply for chemical firms this year

$ Millions	Sales	Change from 1979	Earnings before taxes	Change from 1979
Akzo (9 months)	$ 4,707.9	3.8%	$ 74.1	−49.1%
Albright & Wilson (6 months)	523.2	22.5	21.7	−7.5
BASF (9 months)	11,350.3	7.2	634.8	−14.5
Bayer (9 months)	11,979.0	10.2	582.9	−9.9
Ciba-Geigy (6 months)	3,886.5	19.0	na	—
DSM (6 months)	4,042.2	25.8	95.0	a
Fisons (6 months)	540.2	9.0	12.7	−29.0
Hoechst (9 months)	12,218.2	11.7	646.4	−5.6
Hoffmann-La Roche	1,779.1	9.2	na	—
Imperial Chemical Industries (9 months)	10,226.8	10.0	511.5	−48.0
Laporte (6 months)	244.3	10.3	13.1	−36.0
Montedison (6 months)	4,655.1	25.4	na	—
Rhône-Poulenc (9 months)	4,512.2	8.3	73.4[b]	−32.3
Sandoz (6 months)	1,554.2	9.9	na	—
Solvay (6 months)	2,396.5	14.3	59.7[b]	−8.0
UCB (6 months)	414.1	11.9	9.1[b]	2.0

a Pretax loss in 1979. b Earnings after taxes. na = not available.

are those with heavy involvement in commodity chemicals and petrochemicals, bulk plastics, and man-made fibers.

Akzo, the fibers and chemicals giant headquartered in Arnhem, the Netherlands, provides an example of current company misfortunes. In the past year's third quarter, it suffered a pretax loss of almost $20 million compared to earnings of nearly $48 million in the comparable 1979 period (calculated at the same currency conversion rate of 1.96 guilders to the dollar). This reversal served to pull Akzo's first nine months' pretax income down 50% from the year-ago level of $74 million.

An analysis of the business components that make up Akzo's operating income points up the heavy drain caused by weakness in fibers. Its loss in man-made fibers approached $46 million during the first nine months this year and about $39 million in the third quarter alone. The other segments of Akzo's business at least remained in the black, despite a noticeable dip.

Courtaulds and Imperial Chemical Industries, also both heavily committed to man-made fibers, haven't escaped the ordeal. During the first half of Courtauld's fiscal year, which ended Sept. 30, sales fell 3% from the comparable 1979 level to just over $2 billion. Pretax profit, however, took a 91% tumble to $6.7 million. And for the first time ever, ICI suffered a loss of $24 million in this year's third quarter in contrast to a pretax profit of $371 million in last year's third quarter. "There is little prospect of a marked improvement in profitability before the end of the year," is the company's terse comment.

Montedison of Italy, which like Akzo had spent several years in the red and which, too, seemed at last to be well on the road to profitability, finds itself back in the red again this year. For France's Rhône-Poulenc, the first nine months' net profit of $73 million represents a 32% decline from the same period last year.

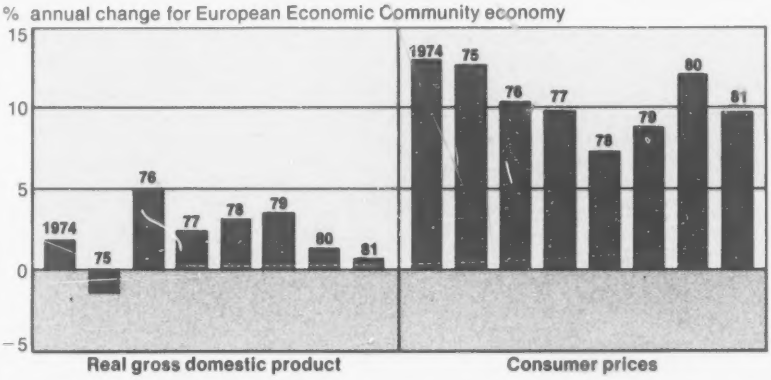
West Germany's three largest chemical companies—BASF, Bayer, and Hoechst—underwent much the same fate. Compared to the like 1979 period, third-quarter pretax earnings were down almost 50% for BASF (to $139 million), 63% for Bayer ($75 million), and 42% for Hoechst ($145 million).

The obvious reason underlying the weakness of the chemical industry is the current global recession. All the key economic indicators are down in Western Europe. All, that is, except for inflation and unemployment. Consumer prices throughout the European Economic Community as a whole—Belgium, Denmark, France, West Germany, Ireland, Italy, Luxembourg, the Netherlands, and the U.K.—rose 12% on average this year, although the increase in Ireland, Italy, and the U.K. well exceeded this. Unemployment, now about 6% of the EEC labor force, is expected to move closer to 7% next year.

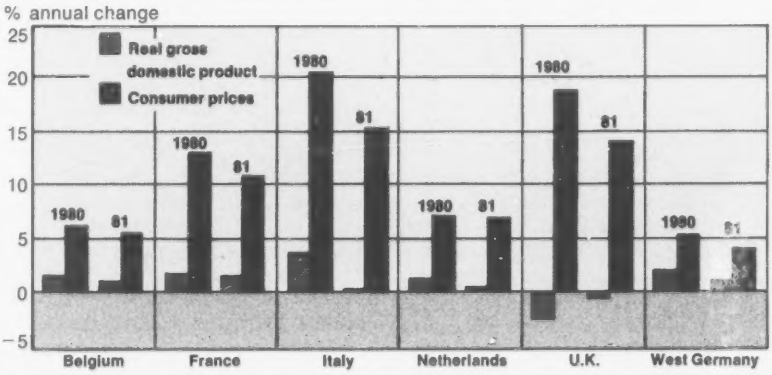
As a consequence, consumer spending has slowed. "The most important direct contribution to the slowdown in [economic] activity has come from the drop in real private consumption in the middle of 1980," points out the Commission of the European Communities in its annual economic review. "Domestic demand as a whole has slowed down more sharply than exports and production, from a 4.6% growth in 1979, to 1.1% this year.

"The economic performance of the Community no longer can be measured mainly on the basis of simple criteria like the rate of growth of gross domestic product (GDP) from one year to the next. The major criterion has to be the capacity to gain control over and modify long-term trends. This implies reducing dependence on imported oil, facing up to increasing competition in the world market, [and] strengthening the structural base of the economy through an increase in the investment ratio."

European growth slumps as prices continue to spiral...

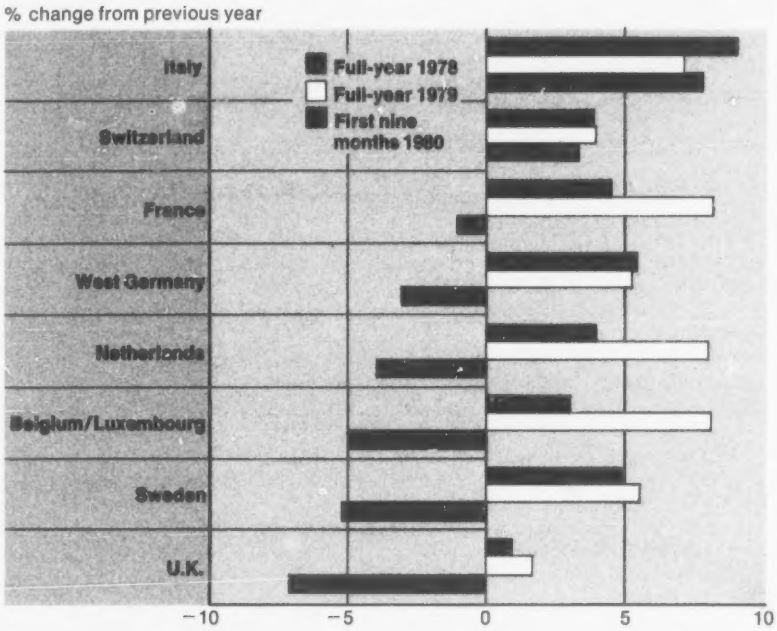


...with prospects bleakest for the U.K. and Italy



Source: Commission of the European Communities

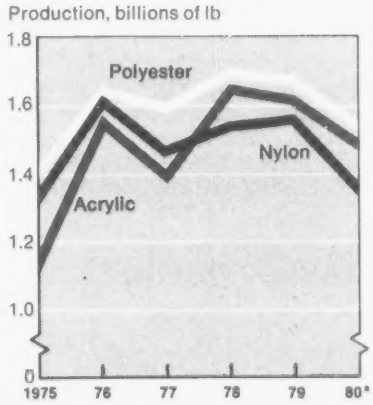
Chemical production is down in most of Western Europe



Note: Data exclude synthetic fibers; data for 1980 for the Netherlands, Belgium/Luxembourg, and Sweden are estimates for the full year. **Sources:** National chemical industry federations for each country

"The prospect of slower overall economic growth has grave consequences for the chemical industry," Govert A. Verheul, a business economist with Akzo, pointed out at a recent European Chemical Marketing Research Association conference in Portugal. There are two aspects to growth of the chemical industry, he explains. One reflects the growth of industry as a whole. The other is surplus or premium growth, resulting to some extent from penetration of chemical products into areas held by such traditional materials as glass, metals, and natural fibers.

European fiber output lowest since 1975



a Estimates. **Source:** CIRFS (International Rayon & Synthetic Fibers Committee)

"The chemical industry in Western Europe now is in a situation where the surplus growth, which has its own life cycle, has attained a stage of maturity," Verheul observes. "In the future, therefore, we will see a fairly low industrial growth of about 2.5% a year, and also a low surplus growth—about 1% a year for chemicals overall and 1.5 to 2% for basic chemicals."

Verheul's projection of a growth rate for basic chemicals of about 4 to 5% matches what others were saying at a recent Society of Chemical Industry meeting in Zurich. But they might be overoptimistic, both in their assumption of the basic industrial growth rate and of the magnitude of chemicals' premium growth. "What if it doesn't happen that way?," asks Keith Walley, managing director of Shell Chemicals U.K.

Others share Walley's caution. "We must now seriously question the so-called chemical premium, the premium of chemical growth over industrial growth generally," ICI's Harvey says. "If basic GDP growth is low, is there any premium [growth for chemicals] at all? There may be a cutoff point somewhere. One reason is that we have passed the substitution phase for many of the products being made. If a chemical's growth rate is higher than the background industrial growth, you must either be creating a new use for it or substituting it for an older material."

The stagnation in chemical demand that has developed this year has meant that plant utilization in Western Europe is down.

Hoechst's situation is fairly representative. "There was a fall in capacity utilization during the third quarter, especially in the dyes, pigments and intermediates, organic chemicals, and plastics divisions," says chairman Rolf Sammet. "Capacity utilization averaged 66%, compared to 80% in the second quarter. In a number of units it has now become necessary to introduce short-time working."

In the case of ethylene, consumption in Western Europe will amount to 23.3 billion lb this year. That's almost 12 billion lb (34%) below the total effective plant capacity of 35.2 billion lb. According to projections made by the European Council of Chemical Manufacturers' Federations (CEFIC) in Brussels, demand by 1984 is expected to rise to 30.6 billion lb, 8.1 billion lb (21%) below effective capacity that year. For propylene, the gap between demand and effective capacity is wider: 8.3 billion lb (42%) this year and 5.9 billion lb (28%) likely in 1984.

Synthetic rubber producers, too, are hurting. Because of a downturn in automobile output, decline in tire sales, and large imports from the U.S. this year, some West European plants are operating at between 35 and 40% of capacity. For polychloroprene, which usually is the first synthetic rubber market to be depressed in times of a recession, demand will be down about 20% from 1979. Comments Donald Bennett, chairman of International Synthetic Rubber Co. in the U.K., "We are experiencing the most awful period of our industrial business since we started about 25 years ago."

The encroachment of U.S. chemicals on West European markets generally is a growing concern this year. What rankles European producers is the advantage to U.S. chemical companies of relatively lower energy prices and the cheaper cost of hydrocarbon feedstocks, in some cases as much as 20% less than Europe's. The disparity stems from the regulated price of U.S. domestic oil and gas.

This, Europeans argue, amounts to unfair competition on the part of the U.S. And even though the price of U.S. oil will be deregulated next October and that of U.S. natural gas in 1985, much damage could be caused to the European petrochemical industry before the effects of the higher U.S. prices filter through to oil- and gas-based products.

U.S. petrochemical products shipped to Western Europe range across the board from individual chemical intermediates to synthetic

Imports of several chemicals from U.S. are up sharply

Imports to EEC countries from U.S., millions of lb	1979	1978	1977	% change 1977–79
Acetone	73.2	14.6	6.0	1121%
Acrylonitrile	48.7	9.6	6.1	698
Adipic esters	2.8	1.2	0.5	489
Aniline	18.9	0.4	0.2	8130
Cumene	11.3	28.6	0.0	—
Cyclohexane	384.9	300.8	325.1	18
1,2-Dichloroethane	24.9	5.8	4.1	509
Methanol	79.6	27.5	62.6	27
Phenol	22.3	6.9	5.3	325
o-Xylene	136.4	122.2	112.3	22
p-Xylene	333.6	283.7	221.5	51

Source: Commission of the European Communities

rubbers, fibers, and carpets. Styrene-butadiene rubber imports from the U.S., for example, increased from 17.2 million lb in 1978 to 39.6 million lb last year. By June of this year, they were arriving at an annual rate of 110 million lb. However, the total for the full year probably will be somewhat less, ISR's Bennett believes, because of a pickup in U.S. demand and a resulting drop in exports.

The story is the same for bulk plastics. Nearly 128 million lb of U.S. low-density polyethylene arrived in Western Europe during this year's first half, in contrast to 44 million lb in 1978 as a whole. The rise for polypropylene is even more dramatic. Between January and June this year, imports from the U.S. were nearly 51 million lb, up from just 15 million lb in 1978.

European imports of U.S. synthetic fibers and of carpets made from them have undergone a dramatic increase, too. The EEC countries took a total of 51.4 million lb of nylon yarn, staple, and tow in 1979, up 43% from 1978. And if a projection from this year's first quarter is valid, that will increase to about 58 million lb in 1980.

Polyester fiber imports increased 204% from 1978 to 1979 to 123.9 million lb. By the end of last March, the level for 1980 as a whole appeared to be heading up a further 32% to 163 million lb. Only for acrylic staple is there a decline. Based on first-quarter imports, 1980 might see 29 million lb coming into EEC from the U.S., down 26% from last year, although for 1979, the 39.2 million lb imported was more than 66% ahead of 1978.

European imports of U.S. synthetic fibers and of carpets made from them have undergone a dramatic increase, business from the U.S. They claim that some U.S. products are being sold in their home territory at dumped prices. CEFIC is investigating such claims against more than 20 chemicals and has presented cases to the Commission of the European Communities on four: styrene, vinyl acetate, and *o*- and *p*-xylene.

The drawing up of an antidumping claim is a lengthy and arduous task, notes CEFIC's Gareth H. Davies, who is spearheading the investigations. On the one hand, one must accumulate data to show that the selling price in Europe is less than it is in the U.S. supplier's domestic market after taking account of freight and other costs associated with delivery. In addition, proof of serious injury to European producers must be proved. The commission, for its part, then examines each claim and makes its own evaluation.

Western Europe

Late last month, the commission set a provisional antidumping duty of 10.6% on U.S. vinyl acetate entering EEC. Celanese material is exempted because no evidence of dumping has been found to date. So is vinyl acetate supplied by U.S. Industrial Chemicals. USI, the commission notes, "has voluntarily undertaken to increase its price to levels which eliminate the dumping margin found."

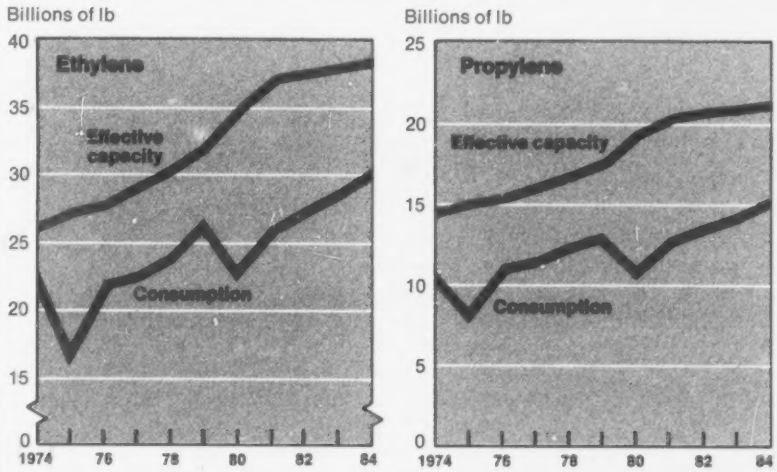
Dumping apart, there are those who maintain that the mere knowledge that U.S. petrochemicals can be obtained in Europe at lower prices in itself tends to weaken the price structure of local manufacturers, particularly at a time of slow demand. As one observer puts it, "It isn't necessary for a single ton to cross the Atlantic. If a buyer here tells us he can get material from the U.S. Gulf Coast at a price below ours, we tend to meet it. We know we are operating our plant at 60% of capacity and that if we don't meet the lower price we will be operating at 50% and be dead. So who is causing the injury? Is it the supplier on the Gulf who is offering his product at a perfectly legitimate price from his point of view, or is it the person here who is holding the threat over our head?"

Under such circumstances, quite modest tonnages of U.S. product coming on the European market can have a ripple effect on European prices. Moreover, the price differential is reinforced further by the weakness of the dollar against the major European currencies.

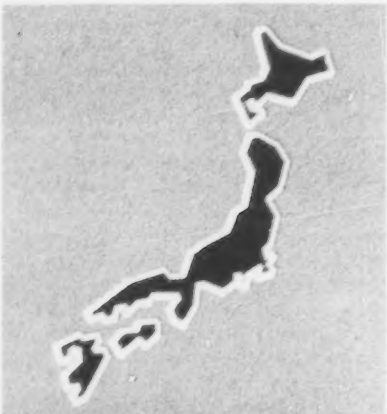
Flying, seemingly, in the face of the current European consensus, ICI's Harvey takes the view that "We could make too much of the U.S. threat. It has been an added disturbing thing. But the prime cause of our problems has been our own weakness as European producers. Even if all the American market penetration went away, we would have to do a lot to put our own house in order to get things back right again."

The list of companies taking steps to do just that reads like a roster of the petrochemical and synthetic fiber producers of Western Europe. Included are BP Chemicals, Courtaulds, Du Pont, ICI, Monsanto, Montedison, Rhône-Poulenc, and Shell Chemicals U.K. The severity and depth of the corporate surgery planned vary. But the aims essentially are the same—to reorganize operations, shed segments that have poor profitability and low growth prospects, and to reduce overhead expenses and staff. □

Western Europe faces potential olefins glut in early 1980's



Source: CEFIC (European Council of Chemical Manufacturers' Associations)



Revival in doubt for Japan's chemical industry

Japanese petrochemical firms are caught between lower demand at home and increased competition in their export markets

Earl V. Anderson, C&EN New York

"The outlook for the Japanese petrochemical industry is by no means bright."

The Japanese chemical executive who said that had the industry's long-term outlook in mind. He was referring to such problems as the increasing price and unreliable supply of feedstock. He was thinking of the sad but undeniable truth that Japanese petrochemicals are becoming less competitive in the all-important export market, especially in Southeast Asia.

He recognized that Japanese petrochemical companies will be extremely cautious about expansion plans. New plants will be built only if they are backed up by less expensive feedstock, can use a more efficient process, introduce a new product, or replace old and obsolete plants.

For Japan's petrochemical industry, the long-term emphasis will be on developing new, high-technology products at home and transferring their basic skills overseas by investing in foreign ventures.

That's the long-term scenario. But these concerns just as easily apply to the situation in which the Japanese petrochemical industry finds itself today. That situation, too, is by no means bright.

Demand for petrochemicals in Japan started cooling down early this

Weakness shows up in chemical output this year, especially for petrochemicals

Thousands of metric tons unless otherwise indicated	1979	Seven-months 1980	Seven-months 1979	% change
INORGANIC CHEMICALS				
Ammonium chloride	753	436	427	2%
Ammonium sulfate	1883	1129	1094	3
Calcium carbide	570	342	333	3
Calcium superphosphate	568	386	342	13
Carbon black	538	334	307	9
Chlorine, liquid	729	466	408	14
Hydrochloric acid	528	328	284	15
Nitrogen[a]	4150	2650	2313	15
Oxygen[a]	7070	4107	4128	−1
Sodium carbonate	1355	828	764	8
Sodium hydroxide	3021	1930	1644	17
Sodium silicate	714	409	413	−1
Sulfuric acid	6581	4023	3783	6
Titanium dioxide	185	108	110	−2
ORGANIC CHEMICALS				
Acetaldehyde	583	290	349	−17
Acetic acid	502	258	303	−15
Acetone	254	150	152	−1
Acrylonitrile	579	290	346	−16
Benzene	2178	1315	1211	9
Butadiene	668	369	384	−4
Butanol	252	142	142	0
Caprolactam	437	263	247	6
Cyclohexane	509	297	286	4
Dioctylphthalate	259	155	143	8
Ethylene dichloride	2110	1313	1150	14
Ethylene glycol	572	308	306	1
Ethylene oxide	593	333	330	1
Methanol	940	558	568	−2
Octanol, synthetic	264	152	139	9
Phenol	244	128	148	−14
Phthalic anhydride	284	152	170	−11
Propylene	3096	1668	1785	−7
Propylene glycol	168	97	96	1
Styrene	1238	740	707	5
Terephthalic acid	613	360	375	−4
Toluene	925	564	686	−18
Toluene diisocyanate	66	39	53	−26
Xylene	1317	752	790	−5
Urea	2083	1126	1233	−9
PLASTICS				
Phenolic resins	300	185	176	5
Polyethylene	2165	1210	1212	0
Polypropylene	1023	586	562	4
Polystyrene	1227	738	699	6
Polyvinyl chloride	1583	911	857	6
SYNTHETIC RUBBER	1107	684	630	9

a Millions of cubic meters. Source: Ministry of International Trade & Industry

year. It soon became apparent that last year's surge in shipments was, in large part, the result of speculative buying. Customers were building up inventory in anticipation of price increases.

As the Japanese economy slowed down, customers started working off their inventories. Demand for petrochemicals dropped. Production cutbacks were the order of the day.

What has happened to ethylene, the barometer of the petrochemical industry, is typical of many other petrochemicals in Japan. Last year, ethylene production hit 4.8 million metric tons, a record for Japan. This year, ethylene output probably will be no greater than 4.1 million or 4.2 million metric tons, 12 to 15% lower than in 1979.

The year started off well enough for ethylene producers. In the first quarter, they churned out 1.22 million metric tons of ethylene, which, on an annual basis, was slightly better than 1979's record performance. But during the second quarter, output slipped 4%.

By June, the 12 Japanese ethylene producers, led by Mitsubishi Petrochemical and Mitsui Petrochemical Industries, started curtailing production. Third-quarter output plummeted 26% to only 864,000 metric tons.

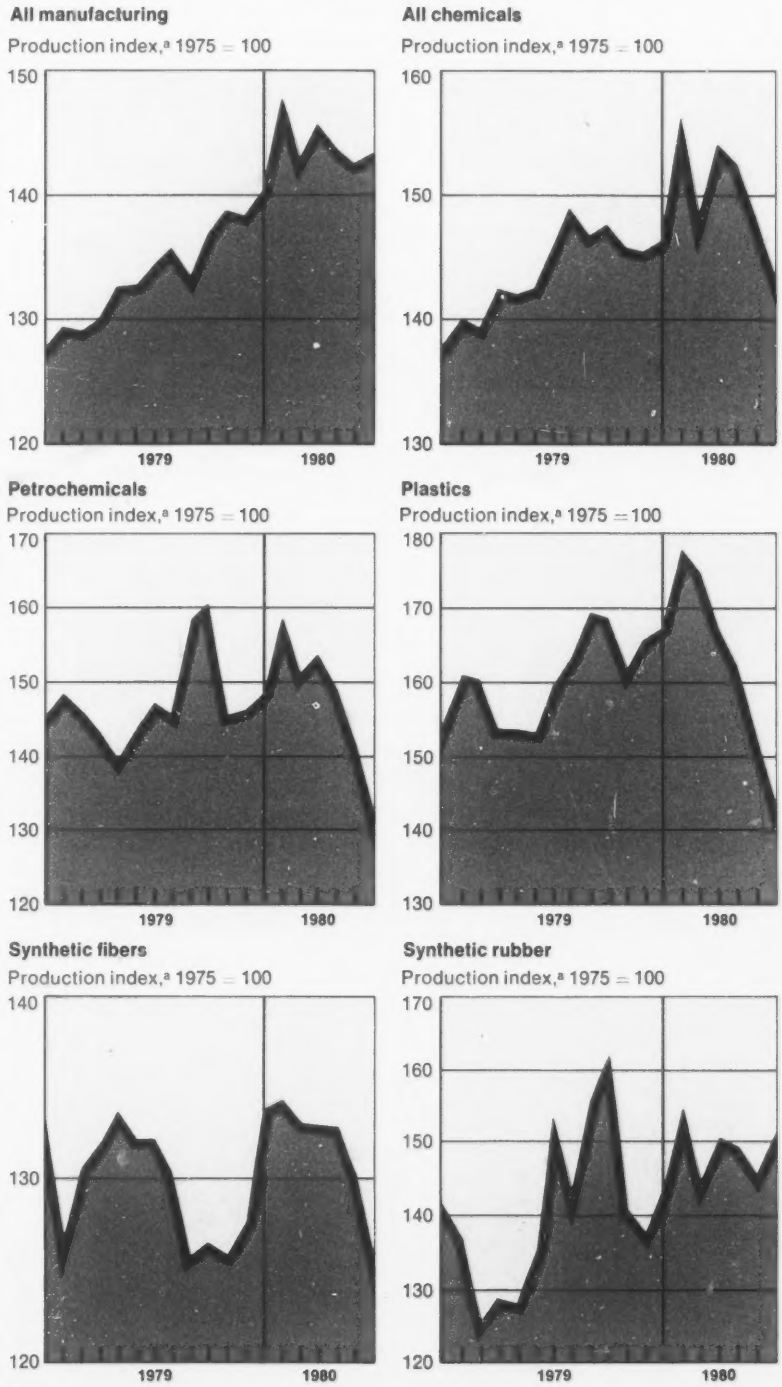
The deteriorating ethylene situation merely reflected what was happening to many of its derivatives, as well as to other petrochemical products.

Demand for the major thermoplastics, for instance, is well below that of last year. In this year's third quarter alone, demand was running from 23 to 37% below last year's pace. Worst hit was polyethylene. Demand for low-density polyethylene was down 37%. For high-density polyethylene, demand was 35% lower than in the third quarter of 1979.

Synthetic fibers are in the same boat. There is still no indication that fiber producers can expect much improvement soon.

To correct a severe overcapacity in synthetic fibers, producers have been shutting down old units under a government antirecession law. Teijin will scrap parts of its polyester filament and nylon filament and staple units, idle for a long time, by March 1981.

Chemical production has been declining in Japan



a Seasonally adjusted. **Source:** Ministry of International Trade & Industry

Kuraray is doing the same with its polyester filament capacity. Unitika already has scrapped 60% of its closed nylon facilities; the remainder will be scrapped by next March.

Until recently, some optimistic Japanese chemical executives were hoping that their fortunes would improve in this year's fourth quarter, so that they would be back on a strong growth track by the first quarter of 1981. Their optimism was based on the belief that production of several petrochemicals hit bottom in the third quarter.

Ethylene output in October, for instance, was 280,600 metric tons, up 4% from September for the first increase in five months. But output still was a third lower than in October 1979, and estimates for the full fourth quarter peg ethylene production at only 890,000 metric tons, a scant 3% improvement over the third quarter.

Now, even the optimists are starting to have their doubts. Demand still is running behind projections and any fourth-quarter improvement will be marginal at best.

Thermoplastics demand is described as "still dull." Customers are insisting on price cuts that producers, who want to raise prices, can ill afford.

Demand for synthetic fibers also is lower than expected. The outlook isn't rosy even well into next year.

According to one Japanese chemical company official, the industry "has gone through hell" this year and probably won't fare much better until well into next year. Its battle scars are bound to show up on the bottom line of company annual reports.

For most Japanese chemical companies, the current fiscal year ends March 1981. But already the scars are evident. In its financial statement for the six months ended September 1980, Asahi Chemical Industry reported that pretax profits were down 25% from the prior six months.

Asahi expects earnings to fall even further during the six-month period which ends next March. The company estimates that, for the full fiscal year, profits will be 19% lower than the previous year.

For Mitsui Petrochemical, the situation is even worse. Its pretax profits were off 40% during the six months ended in September.

Mitsui describes prospects for the second half of the fiscal year as "bleak" and expects a further drop in profits.

As if the situation weren't bad enough at home, Mitsui blames at least part of its misfortune on a declining export market for petrochemicals. Japanese petrochemical exports have indeed been hurt, especially because U.S. exports have been making significant inroads into the Southeast Asia market.

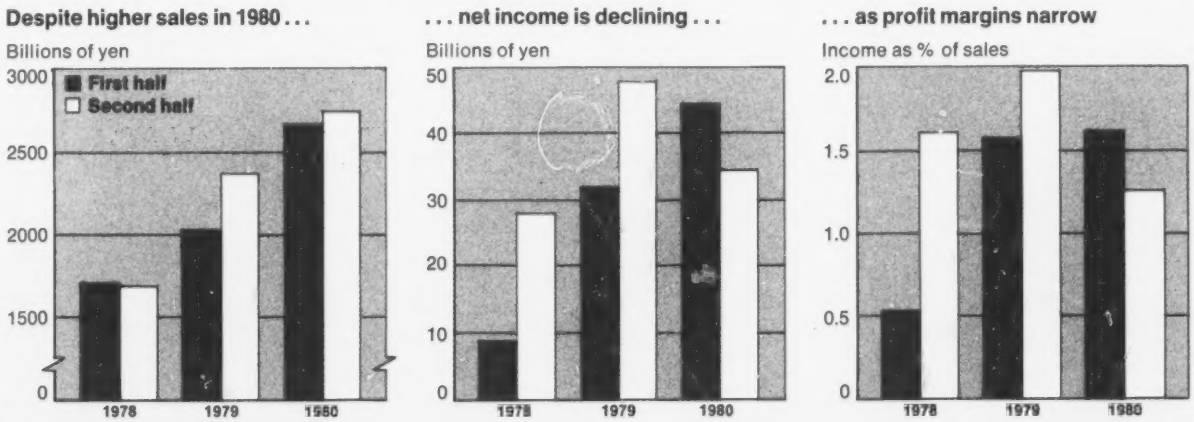
Until recently, that market has been almost the exclusive domain of Japanese chemical companies. Now they are losing their foothold not only to the U.S., but to new competition from South Korea, Taiwan, Singapore, and even the Middle East. And there are signs that Canadian petrochemical producers are starting an export drive in Southeast Asia that also will increase the pressure on Japanese chemical companies. As a result, Japanese petrochemical exports, which account for 10 to 20% of production, probably will continue to decline.

Meanwhile, Japan's chemical imports are rising noticeably. This year, they probably will hit $6.2 billion, up 20% over 1979. In the past three years, Japanese chemical imports have doubled.

Imports from the U.S. are becoming a particular problem for Japanese chemical companies. Large-volume shipments of ethylene glycol, styrene monomer, acrylonitrile, and ethylene dichloride are making it even more difficult than it already is for Japanese companies to revive production rates. They are hoping that a recovery in the U.S. economy will siphon chemicals away from their market back into the U.S. market. But prospects aren't very promising.

The next few months—indeed, the next few years—won't be easy for Japan's petrochemical industry. □

Japanese petrochemical companies face a tough financial year:



Note: Six-month data are for fiscal years ending March 31. Based on results and estimates of 10 leading Japanese petrochemical companies—Mitsubishi Chemical Industries, Sumitomo Chemical, Asahi Chemical Industry, Toray Industries, Mitsui Toatsu Chemicals, Teijin, Showa Denko, Mitsubishi Petrochemical, Dainippon Ink & Chemicals, and Sekisui Chemical. **Source:** Toyo Keizai Shinposha

Petrochemical capacity surges in Latin America

Despite economic problems, Mexico, Brazil, Argentina, and Venezuela all have plans to expand output to meet growing demand

Earl V. Anderson, C&EN New York

In Latin America, chemical markets continue to grow and petrochemical development continues to roll merrily along.

As they have been for the past several years, Mexico and Brazil continue to be the Latin American petrochemical hot spots. Meanwhile, Argentina and Venezuela are struggling to bring their petrochemical industries up to the potential that their domestic markets and raw material base seem to justify.

Mexico, despite its newly increased oil and gas wealth, has its economic problems. Its inflation rate is running at about 30% annually. Transportation bottlenecks keep equipment from reaching plant construction sites and products from reaching markets. An expansion binge has been straining money markets. Price controls, food shortages, and stepped-up labor needs pose economic burdens.

Through it all, Mexico's petrochemical development is nothing short of spectacular. Focal point of this development is Petroleos Mexicanos (Pemex), the state-owned oil company which, by law, has exclusive control over basic petrochemicals production.

Skeptics both inside and outside Mexico scoff at Pemex's production statistics, its announced goals, and its construction timetable. There's some justification for that. But discounted or not, those production figures, goals, and expansion plans are impressive.

Last year, Pemex produced 6.3 million metric tons of the 37 basic petrochemicals that it controls, almost 10% more than in 1978. This year, output is running 30% higher and another 25% increase is expected in 1981.

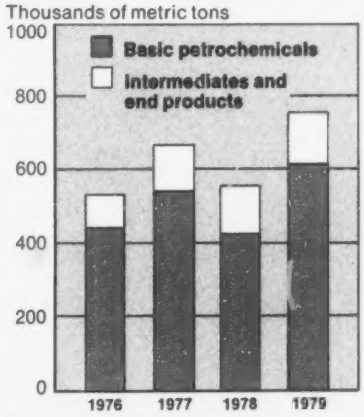
Next year, the long-delayed La Congrejera petrochemical complex likely will start having an impact on production. The oxygen plant there now is starting up. Acetaldehyde and ethylene oxide capacity will come on stream early next year. Plants to make ethylene, aromatics, styrene, and low-density polyethylene will follow. Another complex, at Morelos, with a 500,000 metric-ton-per-year ethylene plant at its core, already is under construction. The eight plants planned there originally already have been increased to 14.

Pemex had planned to invest $2.16 billion in petrochemical plant construction between 1977 and 1982. That already has been increased to $3.15 billion. Now, Pemex again is planning to sweeten the kitty. It is going to build three new petrochemical complexes: at Laguna del Ostion, at Altamira, and at Dos Bocas. All three locations are ports slated for development under the National Industrial Port Development Program. These three projects represent an additional investment of $2.2 billion. About $750 million of this will be spent by 1982.

Unlike Mexico, Brazil has very little hydrocarbon resources. Its now-famous National Alcohol Program is designed to replace large volumes of gasoline with fermentation ethanol. In addition, ethanol will be used as petrochemical feedstock in the future, just as it is to a limited extent now. But, despite all of the rhetoric about an alcohol-based chemical industry in Brazil, ethanol seems destined to be only a supplemental feedstock, used primarily where logistics favor it.

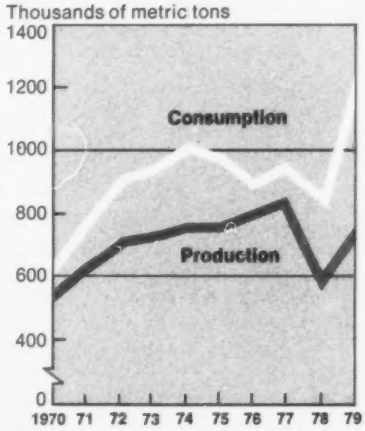
Naphtha will continue to be the primary petrochemical feedstock in Brazil. Recognizing this, industry leaders are going to great lengths to

Venezuelan petrochemical output rebounded in 1979



Source: Sociedad Venezolana de Ingenieros Quimicos

Petrochemical use outruns production in Argentina



Source: Instituto Petroquimico Argentino

Mixed results last year for Mexican chemical production

Thousands of metric tons	1979	1978	% change
ORGANIC CHEMICALS			
Acetic acid	64.3	57.1	13
Acetone	24.2	21.2	14
Benzene	70.5	78.8	−11
Butadiene	17.3	18.3	−5
Ethylbenzene	32.6	36.6	−11
Ethylene	342.7	258.0	33
Ethylene dichloride	97.3	96.5	−1
Ethylene oxide	24.3	26.3	−8
Ethylene glycol	52.9	56.4	−6
Formaldehyde	53.6	47.9	12
Methanol	174.0	102.8	69
Phenol	20.3	18.2	12
Propylene	159.9	138.4	16
Styrene	31.2	37.8	−17
Terephthalic acid	66.0	54.7	21
Toluene	107.9	123.8	−13
Urea[a]	138.4	156.0	−11
Vinyl chloride	55.7	55.7	0
Xylenes, mixed	66.0	76.1	−13
p-Xylene	36.1	37.2	−3
PLASTICS			
Polyethylene, high-density	58.4	3.3	1670
Polyethylene, low-density	95.6	96.4	−1
Polystyrene	80.1	51.4	56
Polyvinyl chloride	106.8	97.6	9
INORGANIC CHEMICALS			
Ammonia	1653.0	1579.0	5
Ammonium nitrate[a]	44.9	36.9	22
Ammonium sulfate[a]	217.1	169.8	28
Chlorine	170.6	175.4	−3
Hydrochloric acid	119.1	97.4	22
Nitric acid	174.0	173.4	1
Phosphoric acid	317.0	346.2	−8
Sodium carbonate	412.2	435.5	−5
Sodium hydroxide	230.9	247.2	−7
Sulfuric acid	2425.3	2372.4	2

a Thousands of metric tons of nitrogen. **Source:** Asociación Nacional de la Industria Quimica

explain to an oil-poor nation that upgrading oil to petrochemicals represents what they are calling "the most noble" use of oil. They have a selling job on their hands.

Brazil's chemical industry, though growing and viable, faces several thorny problems in the immediate future. With inflation roaring along at 113% annually, private companies are complaining that price controls are eroding the profits that are needed to finance expansions. And there's no doubt that expansions will be needed. One industry official estimates that capacity must be doubled to meet demand in the late 1980's.

Another big question in Brazil is how to execute that expansion. Last year, the country's second major petrochemical complex came on stream at Camacari (the first is at São Paulo). A third is being built at Rio Grande do Sul.

But an argument is raging over a possible fourth petrochemical complex. Public officials of several Brazilian states, aware of what a huge petrochemical development can do for their economy, are pushing for a fourth complex. Many officials in the industry argue that the most economical way to add new capacity is to expand existing units.

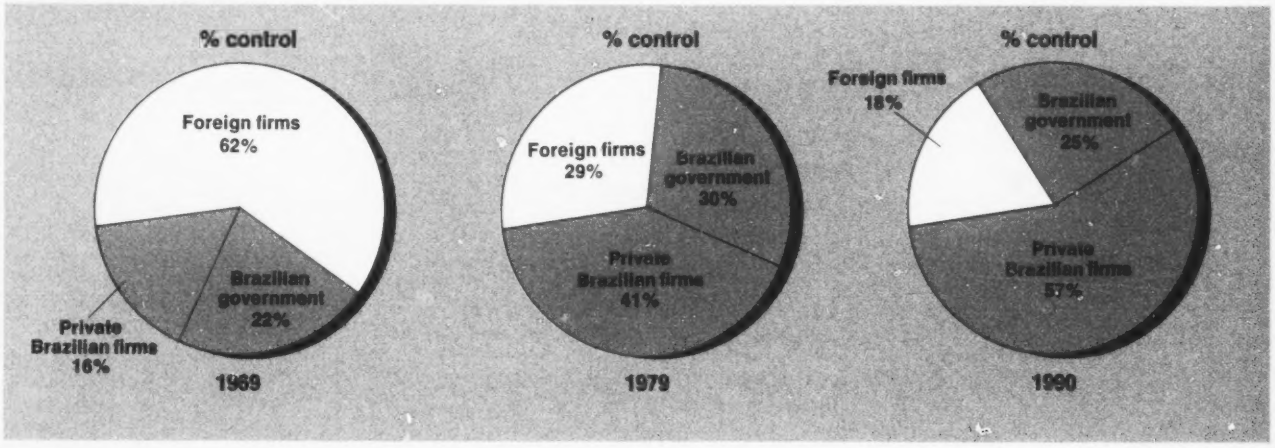
Right now, it's anybody's guess how the issue will be decided. But it's no secret that in Brazil many decisions such as this are based on politics rather than economics.

In Argentina, the economy is sluggish. Unemployment, bank failures, and bankruptcies have marred the economic landscape. Inflation is running about 100% annually.

Along with textiles, paper, and iron and steel, the chemical industry's plant operating rate hasn't been nearly so high this year as it was in 1979. There's little hope that production will match last year's 762,000 metric tons or that consumption will equal the 1.2 million tons of 1979, which was a very good year for Argentine petrochemicals.

Nevertheless, forecasters are optimistic that petrochemicals demand will grow rapidly throughout the early 1980's. Ethylene demand, for instance, is expected to jump from this year's 145,000 metric tons to 262,000

Foreign ownership of Brazil's petrochemical industry is declining as its capacity expands



Source: Associacão Brasileira da Industria Quimica e de Produtos Derivados

Petrochemical output has been expanding at a fast clip in Brazil

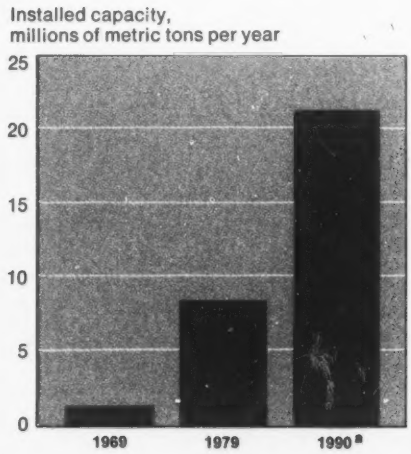
Thousands of metric tons	1979	1978	% change
ORGANIC CHEMICALS			
Acetic acid	53.6	47.3	13%
Benzene	259.3	171.7	51
Butadiene	131.8	81.1	63
Cumene	98.8	98.3	1
Ethylbenzene	199.8	—	—
Ethylene	631.2	398.8	58
Ethylene dichloride	49.1	—	—
Ethylene oxide	87.3	39.6	120
Ethylene glycol	65.8	15.2	333
Formaldehyde	138.1	118.4	17
Methanol	107.2	64.9	65
Phenol	68.8	70.1	−2
Propylene	376.5	237.9	58
Styrene	197.8	145.4	36
Terephthalic acid	67.4	5.8	1062
Toluene	86.0	72.2	19
Urea	151.9	113.4	34
Vinyl chloride	102.5	106.5	−4
p-Xylene	50.1	—	—

Thousands of metric tons	1979	1978	% change
PLASTICS			
Polyethylene, high-density	119.3	52.9	126
Polyethylene, low-density	290.3	218.5	33
Polypropylene	98.3	24.5	301
Polystyrene	72.2	87.2	−19
Polyvinyl chloride	182.5	172.9	6
INORGANIC CHEMICALS			
Ammonia	331.6	258.8	28
Ammonium nitrate	213.7	227.6	−6
Ammonium sulfate	89.1	59.1	51
Carbon black	132.4	125.4	6
Chlorine	396.8	503.2	−21
Hydrochloric acid	245.9	237.3	4
Nitric acid	294.6	352.5	−16
Phosphoric acid	183.2	169.9	8
Sodium carbonate	29.5	23.0	28
Sodium hydroxide	533.3	572.2	−7
Sulfuric acid	1893.7	1578.5	20

Source: Abiquim (Associacão Brasileira de Industria Quimica e de Produtos Derivados)

metric tons by 1985. Demand for polyethylene likely will just about double and demand for polypropylene more than double in the same time span.

To meet future demand and reduce imports, a huge $2.5 billion petrochemical complex is going to be built at San Lorenzo, 250 miles north of Buenos Aires, by Petroquimica San Lorenzo S.A. It will be the first entirely privately owned petrochemical complex in Argentina. The complex will include a 300,000 metric-ton-per-year ethylene unit, as well as 165,000 metric tons of propylene and 216,000 metric tons of aromatics capacity.



Plans for the San Lorenzo complex are moving ahead fast and call for a completion date in 1985 or 1986. But large petrochemical projects in Latin America have a habit of slipping behind schedule.

Meanwhile, the Venezuelan petrochemical industry is trying hard to get back on a solid footing. One wag likens the state-controlled petrochemical industry to a patient in the intensive care ward. But realistically or charitably, he gives the industry "a good chance" of surviving.

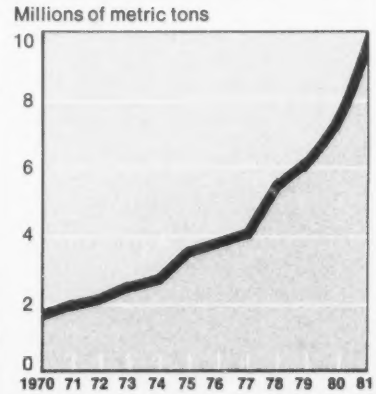
Since coming under government control in 1953, the petrochemical industry has undergone several reorganizations. Now the job of straightening out the industry rests with Petroquimica de Venezuela (Pequiven), a wholly owned subsidiary of the state-owned oil monopoly, Petroleos de Venezuela.

Since it has been under government control, the Venezuelan petrochemical industry has been a consistent money loser. Poor management, unskilled employees (and too many of them), and political pressures have taken their toll.

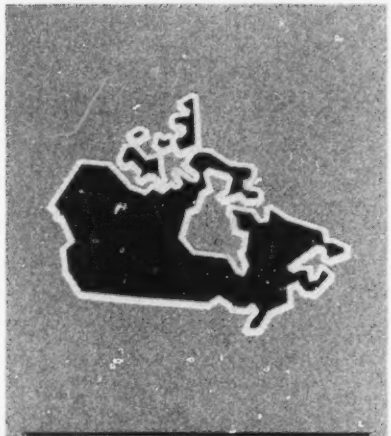
Now Pequiven is trying to straighten out the mess and appears to be making some headway, particularly at its major petrochemical complex of El Tablazo. This complex includes ethylene, propylene, and caustic soda-chlorine units that feed satellite plants located there. Two ammonia and two urea plants also are located at El Tablazo, with all of their output earmarked for export. Other ammonia and urea plants at Moron handle the domestic market.

Despite the country's small population, Venezuelan petrochemical demand is certain to increase over the next few years, and petrochemical officials know that they will have to increase capacity if they are to meet that demand without substantially increasing an already heavy import burden. In particular, they are eyeing aromatics production. Right now, Venezuela produces no basic aromatics. But, with the present Venezuelan aromatics market growing, and with increasing demand for benzene to produce styrene and synthetic rubbers, officials feel that the domestic market soon will justify an aromatics plant. □

Mexico is boosting its basic petrochemical output



Note: Data of 37 primary petrochemicals produced exclusively by Petroleos Mexicanos (Pemex). **Source:** Petroleos Mexicanos



Only modest growth expected for Canadian chemicals

Exports are the one strong aspect of an otherwise lackluster chemical business, with weak demand likely to linger

Ward Worthy, C&EN Chicago

The end of 1980 finds Canada's chemical industry reasonably healthy, but not nearly so healthy as it was at the end of 1979. Although capacity was increased substantially, production of many major chemicals sank. Plastics were particularly hard hit. And although chemical prices generally rose sharply early in the year, those gains later were eroded by weakened demand. Chemical company profitability suffered accordingly. Chemical exports held up well; otherwise, things would have been a lot worse.

Across the board, production of chemicals and related products peaked in the first quarter of 1980. Thereafter, production declined, although not precipitously. By the end of the third quarter, output was about 1% below year-earlier levels. At year's end, there are signs that a turnaround may have begun; nevertheless, 1981 likely will bring, at best, only modest increases.

Counter to the general chemical trend, production of industrial chemicals rose about 4% during the year. Chemicals continue to do better than total manufacturing, for which output had dropped more than 4% by the end of September, compared to year-earlier levels.

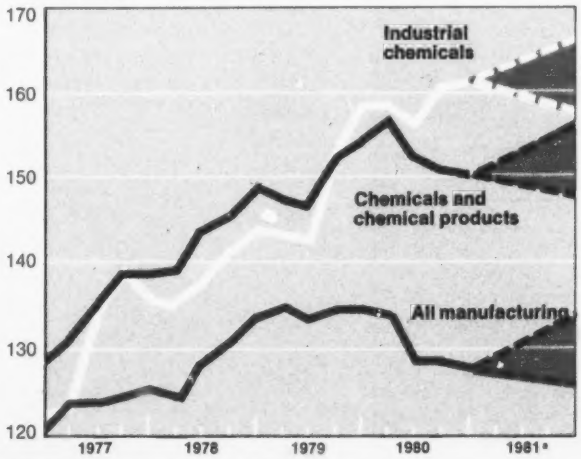
Despite lagging production, the total dollar volume of chemical shipments is up sharply, thanks largely to the steep price increases early in 1980. Shipments in 1980 will amount to about $10.8 billion (Canadian), a 17% increase from 1979's $9.2 billion. That rate of growth isn't likely to continue in 1981; even so, chemical shipments could easily exceed $12 billion next year.

Of course, it's misleading to treat the chemical industry as a monolith. Some segments had a very good year. The value of shipments of mixed fertilizers and of inorganic and organic industrial chemicals is running about 20% ahead of 1979 levels. But in the big plastics and synthetic resins segment, dollar volume of shipments is up only about 14%, reflecting higher prices overriding a substantial decline in output.

Production figures for specific chemicals bear out the trends suggested by shipments data. In 1979, plastics and organic chemicals were the big gainers, while inorganic commodities lagged. This year, it's the other way around. Production of chlorine and caustic soda is running about 30% ahead of 1979 levels, and sulfuric acid is up 22%. Ammonia, after a flat 1979, turned in a 9% in-

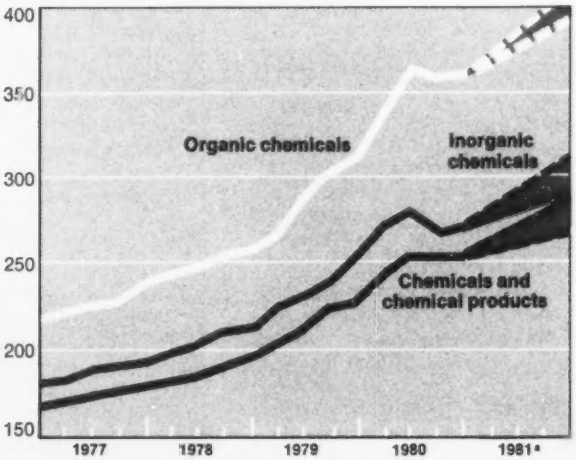
Output of chemicals may show no growth . . .

Volume index, real domestic product, 1971 = 100



. . . but prices will resume upward surge

Industry selling price index, 1971 = 100



[a] C&EN estimates. **Source:** Statistics Canada

crease in 1980, and related fertilizer chemicals also are up substantially.

But after several years of spectacular growth, it was downhill for most plastics in 1980. By the end of September, production of polyethylenes was down almost 6%. Polystyrene and unsaturated polyesters were even harder hit, with output down almost 15%. However, production of polyvinyl chloride increased about 25%, and ethylene production was up 21% in spite of the downturn in polyethylenes. Benzene production, however, was off about 9%.

The picture would be bleaker were it not for continuing strength in chemical exports, which are up about 20% from 1979 levels. At the same time, chemical imports have risen only about 2%. From January through August of 1980, Canada had amassed a $330 million chemical trade surplus. It's unreasonable to expect that chemical exports will grow at the same rate in 1981, but Canada's favorable feedstock prices will continue to give it an export advantage.

In fact, Canada, with its combination of ample hydrocarbon resources and well-developed economic infrastructure, has the potential to become an even greater force in world petrochemical markets in the decade ahead. Chemical companies have known that. Despite the current business sluggishness, construction of new petrochemical plants has continued apace, especially in petroleum-rich Alberta.

Whether that potential is realized depends in large measure on government actions, however. Recent Ottawa energy proposals call for sharply higher taxes on oil and for "Canadianization" of the country's oil industry, which is 70% foreign-owned. Faced with those prospects, oil companies have cut back on exploration and on exploitation of oil sands, and petrochemical producers are now having second thoughts about some of their planned expansions.

Selling price indexes for chemicals rose sharply in the second quarter of 1980; since then, they've dropped somewhat, reflecting the general business weakness. Nevertheless, at the end of September the index for all chemicals and chemical products was about 14% higher than it had been a year earlier.

The price index for industrial inorganic chemicals rose only about 11% in that period, despite a 21% increase for chlorine and a 17% increase for caustic soda. However, prices of industrial organic chemicals were up almost 20%. Those for plastics and synthetic resins, as a group, were up about 13%, but polyethylene prices increased about 16%.

The price outlook for 1981 is clouded by uncertainties about Canadian energy policies and world oil supplies. Although general inflation will tend to drive chemical prices up, weak demand will tend to hold them down, so that 1981 price increases aren't likely to match 1980's.

For Canadian chemical companies, the strong recovery that began in 1979 continued through the first quarter of 1980; after that, things got worse. In the first nine months of 1980, Canada's four largest publicly reporting chemical companies (C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada) had, in aggregate, a 22% increase in net income on a 13% increase in sales, compared to the same period in 1979.

Most of that gain was racked up in the first quarter, however. Earnings during the third quarter for those same four companies dropped 21%, compared to the third quarter of 1979, while sales for the period rose only 5%. Third-quarter profit margins averaged 5.5%, compared to 7.5% in the third quarter of 1979. The companies aren't ready to predict that there will be strong improvement in the months just ahead; neither, however, do they expect a repeat of the debacle of 1975–76. □

Production: slower growth for most chemicals in 1981

Thousands of metric tons per year	1977	1978	1979	1980[a]	1981[a]
Ammonia, anhydrous	2161.8	2397.6	2410.6	2600	2800
Ammonium nitrate	924.8	870.8	909.7	860	860
Ammonium phosphates	1147.3	1178.9	1344.1	1470	1600
Benzene	382.9	487.7	625.7	570	600
Caustic soda, 100% NaOH	1013.8	1036.2	1139.7	1480	1600
Chlorine	888.3	940.7	1034.2	1325	1450
Ethylene	567.3	825.8	1074.0	1300	1450
Hydrochloric acid, 100%	136.2	154.6	154.1	170	180
Phosphoric acid, 100% P_2O_5	555.7	553.8	732.6	800	880
Polyesters, unsaturated	20.9	20.3	27.2	23	25
Polyethylene, low-density	345.0	477.5	391.0	380	400
Polyethylene, high-density			200.1	190	200
Polystyrene	85.2	98.7	119.7	105	110
Polyvinyl chloride	99.7	124.8	152.4	190	200
Sodium chlorate	161.6	199.2	232.8	230	240
Sulfuric acid, 100%	3140.3	3260.8	3685.9	4500	4800
Urea	804.7	1217.2	1211.7	1290	1350

a C&EN estimates. **Source:** Statistics Canada

Slower chemical growth set in U.S.S.R., East Europe

New five-year plans lower goals and investment, reflecting economic problems and concern about foreign debt

Richard J.Seltzer, C&EN Washington

This month, the Soviet Union and its six East European allies in the Council for Mutual Economic Assistance (CMEA)—Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania—complete their current five-year plans. Development of their chemical industries receives high priority in these centrally planned economies, and considerable progress already has been made. However, as in many other of their economic and industrial areas, chemical operations generally are falling far short of meeting the targets established under their national five-year plans.

Only sketchy information is yet available about targets under the next five-year plans, running to 1985, and for 1981 in particular. But the prognosis is for a continuation of slower growth.

Diagnosis of the factors obstructing chemical development reveals a syndrome of ailments similar to those plaguing all industry in the Soviet bloc. These ailments include shortages of raw materials and labor, construction and transportation bottlenecks, low productivity, poor product quality, poor industrial management, and outmoded technology and equipment. Moreover, the region faces increasing difficulties in its energy and feedstock supplies in the next few years, according to U.S. Central Intelligence Agency projections, as Soviet oil production reaches a peak and then declines. And the therapy for these ailments is obstructed by the nature of the economic and political system in CMEA countries.

Industrial production in the region rose nearly 4% in 1979, according to the United Nations Economic Commission for Europe (ECE), down from 5% in 1978 and 6% in 1977. (The 1979 plan called for a 5.7% increase, and the five-year plan targeted a rise of 6.6% per year.)

Industrial growth was slower in every country in 1979, particularly in the U.S.S.R. (3.4% in 1979, compared to 4.8% in 1978 and 5.7% in 1977) and Czechoslovakia (3.7% in 1979 compared to 4.8% in 1978 and 5.7% in 1977). In several countries—the Soviet Union, for example—growth in industrial output in 1979 was the lowest since World War II.

Chemical and rubber industry growth also slowed in every country. Chemical and rubber output in Romania, for example, rose only 1% in 1979, down from 11% in 1978. In the U.S.S.R., production rose only 3% in 1979, according to official figures cited by ECE (the goal was 9%). This compares with a 6% rise in 1978, 6.5% in 1977, and 7.9% in 1976.

Furthermore, preliminary CIA calculations depict an actual decline of 1.4% in Soviet production of chemicals and petrochemicals in 1979. Mineral fertilizer production dropped to 94.5 million metric tons from 98 million in 1978—the first yearly decline since World War II. Output also dropped for plastics and resins (down 1%), synthetic fibers and yarns (down 3%), pesticides and herbicides (down 3.5%), and other key

U.S.S.R. leads East Europe by far in chemical production

Thousands of metric tons in 1979	U.S.S.R.	Bulgaria	Czechoslovakia	East Germany	Hungary	Poland	Romania	TOTAL
Sodium hydroxide (100%)[a]	2,680	107	302	415	194[b]	436	725	**4,860**
Synthetic ammonia[c]	12,750	951	768	1147	767	1513	2315	**20,200**
Sulfuric acid (100%)	22,400	998	1253	990	630[d]	2982	1765	**31,000**
Mineral fertilizers[e]	22,140[f]	959	1140	4740	850	2431	2522	**34,800**
Nitrogen fertilizer[e]	9,170[f]	677	591	900	549	1375	1766	**15,000**
Phosphate fertilizer[e]	6,315[g]	282	358[g]	444[g]	165	932	676	**9,170**
Potassium fertilizer[e]	6,650[f]	—	191[h]	3396	136[h]	124[h]	80[h]	**10,800**
Plastics	3,477[i]	200	853	790	294	441	516	**6,570**
Synthetic rubber	1,867[j]	30	60	150	—	130	149	**2,390**
Synthetic fibers[k]	500	48	97	132	19	161	130	**1,090**

a Including tonnage not commercialized but used on site for processing. b Including regenerated sodium hydroxide. c Nitrogen content. d Including oleum. e On basis of nutrient content (N, P_2O_5, or K_2O, respectively). f Including some product used for technical purposes. g Including production of ground phosphate rock for direct application and phosphate animal feeds. h Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. i Including resins for man-made fibers. j Estimated. k Data for noncellulosic fibers made of either synthetic or natural polymers (for example, based on casein or groundnuts); data exclude waste, glass fibers, and rubber fibers. **Source:** Central Intelligence Agency

chemicals. The shortfalls of fertilizer and pesticides were particularly unfortunate for problem-ridden Soviet agriculture.

Only scattered information is available so far on results in 1980 for the U.S.S.R. and East Europe, but goals are generally not being met. For instance, according to a recent speech by the chairman of the Soviet State Planning Committee, Nikolai K. Baibakov, Soviet industrial production will be up 4% this year, a bit better than last year but still below the 4.5% goal.

The Soviet chemical industry apparently will fall far short of its ambitious 9% growth target for 1980. Indeed, Baibakov specifically criticizes the Ministry of Chemical Industry for not meeting its targets for fertilizer, fibers, and plastics.

Fertilizer production, for example, was 87.1 million metric tons through October—up 11% compared to the same period in 1979—but the goal for all 1980 is a 22% increase. And this goal of 115.3 million metric tons itself represents a drastic scaling back from the original five-year plan target of 143 million by 1980.

To make things worse for Soviet agriculture, pesticide production is continuing to decline, dropping 2% further to 393 million metric tons through October this year. And this year's goal of an 8% rise, to 512 million metric tons, was itself a severe cutback from the five-year plan's original target of 615 million metric tons.

The new, 11th, Soviet five-year plan will be approved at the 26th Communist Party Congress in February. In 1981, according to Baibakov, chemical and petrochemical production is to increase 5%. Fertilizer production is to rise 5% (to 113.8 million metric tons) and synthetic resins and plastics 12%. Output of synthetic fibers and yarns is to grow 51,000 metric tons to a total of 1.3 million metric tons.

The new Soviet five-year plan, as well as those for other East European countries, apparently is scaling down goals to a less ambitious, perhaps more realistic level. This will reflect the bloc's internal economic and industrial difficulties and its concern to reduce its foreign debt.

Thus, Bulgaria has cut its goal for industrial production to an increase of 6% in 1980 (down from an original 8.6%) and 6% again in 1981. Emphasis will be on scientific and technological progress, and the bulk of investment will go for modernization of existing facilities, rather than for whole new projects. In the chemical and rubber industry, the target is 13% growth in 1980, cut from an original 14%, with a goal of 10% in 1981.

Czechoslovakia, East Germany, and Hungary also are slating lower growth rates and investments. For example, Czechoslovakia's overall industrial output is to grow 4% in 1980 and 3.5% in 1981. In the first half of 1980, Czech industrial production rose nearly 4% from the same period last year. East Germany's chemical industry set a goal of 6% growth in output for this year.

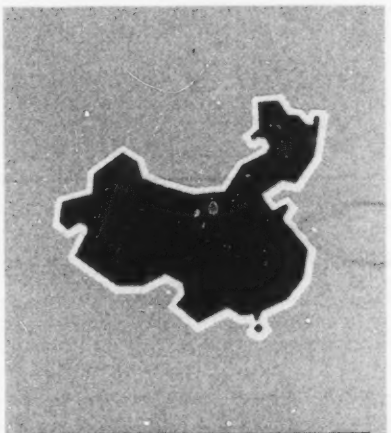
Romania—with the fastest growing economy in East Europe for some years—has slightly lowered its growth targets for 1981–85, but it still plans to increase industrial production 9 to 10% annually. Its chemical industry also is slated for 10% annual growth. Plastics production is slated to grow 50 to 70% between 1980 and 1985, synthetic yarn and fibers 60 to 80%, synthetic rubber 40 to 60%, sulfuric acid 50%, ammonium chloride 100%, sodium sulfate 110%, pesticides 40 to 60%, and pharmaceuticals 100 to 120%.

The outlook is far bleaker for Poland. The current political turmoil and labor unrest worsen the problems of an economy that was already in the worst shape of any East European country. Production of a number of key chemicals dropped in 1979 from 1978 levels: sodium hydroxide down 7%, ammonia 6%, sulfuric acid 6%, mineral fertilizer 7%, and plastics nearly 6%. The picture is unlikely to be better this year. □

Soviet chemical output continues to fall behind targets

Millions of metric tons unless otherwise noted	1981 plan	1980 Plan	1980 10-month result	1979 Plan	1979 Result	1978 result	1980 original target[a]
Mineral fertilizers[b]	113.8	115.3	87.1	111	94.5	98.0	143
% increase[c]	5.4%	22%	11%[d]	13.3%	−3.6%	1.2%	9.8%[e]
Synthetic resins and plastics	4.3	na	3.0	3.8+[f]	3.48	3.52	5.4–6.0
% increase[c]	12%	na	3.4%[d]	9.3%[f]	−1.1%	6.1%	13.7–16.0%[e]
Chemical fibers and yarns	1.3[f]	na	0.98	1.20[f]	1.10[f]	1.13	1.45–1.50
% increase[c]	na	na	7.7%[d]	4.6%	−2.7%	4.0%	8.7–9.4%[e]
Automotive tires[g]	na	na	50.2	na	60.0	59.0	70–72
% increase[c]	na	na	0.6%[d]	na	1.7%	2.3%	6.2–7.0%[e]
Pesticides and herbicides[h]	na	512	393	na	475	492	615
% increase[c]	na	7.8%	−2.0%[d]	na	−3.5%	1.0%	7.0%[e]
Sodium hydroxide (100%)	na	na	2.3	na	2.68	2.76	na
% increase[c]	na	na	na	na	−3.0%	3.7%	na
Sodium carbonate (100%)	na	na	na	na	4.78	4.86	na
% increase[c]	na	na	na	na	−1.6%	−0.4%	na
Sulfuric acid (100%)	na	na	19	na	22.36	22.41	na
% increase[c]	na	na	na	na	−0.2%	6.2%	na

a As planned at start of Five-Year Plan in 1976. b Conventional units. c Increase or decrease from result in previous year. d Increase or decrease from 10-month result in previous year. e Calculated average annual increase required in 1976–80 to reach original 1980 target. f Approximate. g In millions of units. h In thousands of metric tons. na = not available. **Sources:** Soviet official statements and U.S. Department of Commerce



China seeks a base for rapid growth

Restructuring of Chinese industry is now under way, but an oil squeeze is putting its petrochemical plans in jeopardy

Richard J. Seltzer, C&EN Washington

This month, the People's Republic of China completes the second year of its 1979–81 economic readjustment policy. This policy was adopted last year after China found itself overextended by its extremely ambitious development plans, which ran head on into the limitations of its underdeveloped industrial, agricultural, and educational systems.

Aimed at a sweeping restructuring of China's economy and at a reallocation of resources to build up long-neglected sectors, the pragmatic readjustment policy entails a period of slower but more balanced and selective development. Its goal is to lay the basis for more rapid growth later in the 1980's under a 10-year economic plan now taking shape. Indeed, the dimensions of the tasks and changes still before China are likely to mean continuation of the readjustment period for at least another year or two beyond 1981.

According to official Chinese statistics, in 1979 overall industrial production rose 8.5%, far less than the gains of 13.5% in 1978 and 14.3% in 1977. Moreover, the goal for both 1980 and 1981 is a rise of only 6%. (The 1980 target may be exceeded: Through September, production was 11.7% ahead of the same period last year.)

The readjustment policy gives high priority to agriculture and to light and textile industries (producing for export and for long-neglected consumer needs), and low priority to heavy industry. Thus, in 1979 output from light industry was up 10%, while that from heavy industry was 8% higher than in 1978. Through September of this year, light industry's output soared 21% compared to the first nine months of 1979, while production by heavy industry rose only 5%. The goal for 1981, the first year of China's sixth five-year plan, is an 8% increase in light industry's production and a 4% increase for heavy industry's.

The readjustment policy also stresses strengthening of weak infrastructure sectors inhibiting all development, such as the educational system, energy, transportation, communications, and building materials. In addition, the policy entails thoroughgoing reform of industrial management to increase productivity, quality, efficiency, and discipline. This will include introduction of "the positive aspects of a market economy"—giving individual enterprises a considerable amount of freedom to run themselves according to economic and market criteria, and to motivate workers and managers with economic incentives. All this will continue "under the overall guidance of state planning."

Specific chemical industry priorities follow the national plan's emphasis on agriculture and textiles. Fertilizer production rose almost 23% in 1979. Output through October this year was 10.5 million metric tons of nutrient content, up 20% from the same period last year. The goal for 1981 is 12.3 million metric tons.

Synthetic fiber production is also growing rapidly, up 14.5% in 1979, to 326,000 metric tons. In the first half of 1980, output soared 45% to 219,000 metric tons from the same period in 1979, putting production well on the way to this year's goal of 360,000 metric tons.

The chemical industry as a whole increased its output 13% the first half of this year, compared to the first half of 1979. Sodium carbonate production was 832,000 metric tons (up 17% from the first half of 1979), and output of plastics was 14% higher.

One major aspect of the readjustment policy is curtailment of China's overambitious capital construction programs and concentration on consolidation and expansion of existing enterprises. In 1979, 295 large and medium-sized projects were suspended or deferred, and a further 238 were targeted in 1980, including a number of chemical projects. However, capital construction "still far

Fertilizers lead rapid rise in chemical output

Thousands of metric tons, unless otherwise noted	1979	1978	% change 1978–79
Chemical fertilizer[a]	10,654	8691	22.6%
Nitrogen (N)	8,821	7637	15.5
Phosphate (P_2O_5)[b]	1,817	1033	75.9
Potassium (K_2O)	16	21	−23.8
Ammonia[c]	10,727	9287	15.5
Sulfuric acid (100%)	7,000	6610	5.9
Sodium hydroxide	1,826	1640	11.3
Sodium carbonate	1,486	1329	11.8
Calcium carbide	1,407	1238	13.7
Plastics	793	679	16.8
Insecticides	537	533	0.8
Ethylene	435	380	14.5
Synthetic detergents	397	324	22.5
Synthetic fibers	326	285	14.5
Pharmaceuticals	42	41	2.5
Tires (thousands of units)	11,690	9360	24.9

a Nutrient content basis. b Including production of ground phosphate rock for direct application and phosphate animal feeds. c Nitrogen content basis, including only ammonia produced for fertilizer. **Sources:** Central Intelligence Agency, U.S. Department of Commerce, State Statistical Bureau of the People's Republic of China

exceeds the country's present capabilities," according to an official statement early this month. Thus, a new cycle of large imports of chemical technology and plants is unlikely before at least 1983 or 1984.

Indeed, notes Robert H. Silin of Bank of America's Hong Kong subsidiary, BA Asia Ltd., when China bought petrochemical plants abroad on a large scale in 1978 and 1979, it allocated sufficient foreign currency for them, but it apparently underestimated badly the local funds required for infrastructure at each site. This lack of funds and infrastructure will significantly delay several of these projects.

Moreover, China's oil production may not increase significantly until the late 1980's. Crude oil production in 1979 (106 million metric tons) was up only 2% from 1978. The target both this year and next is the same 106 million.

Coupled with increasing domestic demand for oil products, this oil squeeze means that China cannot increase crude petroleum exports to Japan or other countries as planned to pay for imports. Moreover, it raises doubt about the availability of sufficient feedstocks for China's petrochemical industry.

For example, Silin projects that China will increase its ethylene capacity from its current 528,000 metric tons a year to 683,000 metric tons by the end of 1981 and 1.58 million metric tons by 1985. An additional 300,000 metric tons of capacity has already been purchased for startup after 1985. However, Silin points out that unless offshore oil becomes available in large quantities by 1985–90, China's development of olefin-based production will be retarded. Nevertheless, he expects China to become an increasingly significant exporter of petrochemicals in the 1980's, both because it needs hard currency to pay for plant imports and because it will lack the downstream capacity to absorb the output of its new plants.

As its readjustment policy has taken hold, China has beefed up exports to $8.56 billion in the first half of this year, up 44% from last year. It has, moreover, shown greater selectivity in imports—favoring, for instance, imports of technology and equipment to increase the efficiency of its own existing facilities, rather than the costly purchases of whole plants. Imports during the first half of this year increased 20%. China has thus turned around its foreign trade picture, going from a $778 million deficit last year to a $130 million surplus for the first half of this year.

China's trade with the U.S. is soaring, accelerated by removal of political and economic bars through establishment of diplomatic relations early last year and implementation of a bilateral trade agreement early this year (including most-favored-nation status for China). U.S.-China trade is expected to total about $4.1 billion this year, almost double the figure in 1979 and almost quadruple that in 1978. Trade of more than $6 billion is projected for 1981.

U.S. exports (close to two thirds of which are agricultural products) currently account for about 80% of this trade, giving the U.S. a growing trade surplus—$1.9 billion through September of this year. U.S. chemical exports, which contributed $198 million to this surplus through September, have increased from $10 million in 1976 to $272 million in the first nine months of 1980. These figures do not include large amounts of synthetic fibers sold to China by the U.S.

Consistent with China's development priorities, agricultural chemicals (fertilizers and pesticides) and synthetic fibers for textile use top the list of chemical-related U.S. exports. Indeed, polyester fibers ($121.2 million) ranked fifth among all U.S. exports to China through September this year, diammonium phosphate fertilizer ($49.7 million) ranked ninth, and polyester resins ($39.2 million) ranked 11th. Also high on the list are polyester continuous textured yarn ($30.3 million), urea ($23 million), concentrated superphosphate ($15.8 million), insecticides ($18.8 million), and polyvinyl chloride resin ($18.7 million).

U.S. chemical imports from China totaled $73.7 million in the first nine months this year (almost double the total in the same period last year). Inorganic chemicals and natural products dominate. Ammonium molybdate ($16.9 million through September) ranked fifth among all U.S. imports and fireworks ($15.9 million) ranked sixth. Other top imports are antimony oxide ($5 million), menthol ($4.1 million), cassia oil ($3.8 million), and natural drugs ($2.3 million). □

China shows soaring chemical trade deficit with U.S.

$ Millions[a]	9-months 1980	1979	1978	1977	% change 1978–79
Total exports	$8560[b]	$13,755	$10,055	$8108	37%
Total imports	8430[b]	14,533	10,302	6598	41
World trade balance	**130[b]**	**−778**	**−247**	**1510**	—
Exports to U.S.	652	592	324	203	83
Imports from U.S.	2572	1,716	821	171	109
Trade balance with U.S.	**−1920**	**−1,124**	**−497**	**32**	—
Chemical exports to U.S.	74	60	34	22	76
Inorganic chemicals	21[b]	19	4	na	375
Essential oils	na	6	7	6	−14
Rosin and turpentine	na	3	1	1	200
Chemical imports from U.S.	272	125	61	20	105
Inorganic chemicals	na	14	2	na	600
Synthetic resins	55[b]	31	2	na	1450
Fertilizer[c]	na	45	39	8	15
Pesticides	na	19	10	na	90
Chemical trade balance with U.S.	**−198**	**−65**	**−27**	**2**	—

a F.o.b. basis; figures are generally based on data from China's trading partners. b Result for first half. c Excludes phosphate rock, ammonium chloride, sodium nitrate, and potassium nitrate. na = not available. **Sources:** Central Intelligence Agency, U.S. Department of Commerce

Oil, gas, and minerals spur Middle Eastern development

Exports play a key role in development of petrochemical complexes on the Persian Gulf and mineral wealth in Israel

Dermot A. O'Sullivan, C&EN London
Richard J. Seltzer, C&EN Washington

The conflict between Iran and Iraq this year has cast a long shadow of uncertainty over the future stability of the entire Middle East. Immediate concerns, of course, center on how the war will affect crude oil supplies and prices. But many large industrial developments, planned or actually under construction, also could be in jeopardy.

The major petrochemical project going in at Bandar Khomeini (formerly Bandar Shapur), on the northern part of Iran's Persian Gulf coast, is one casualty of the war. The $3.5 billion complex has been hit by several bombing attacks, and work there has come to a halt. Earlier, ill-fated Iran-Japan Petrochemical, the company building the complex, had fallen foul of political unrest when construction was suspended in the wake of the Iranian revolution.

The project is a joint venture between National Iranian Oil Co. and Iran Chemical Development Corp., a consortium of Japanese companies in which Mitsui holds the largest share. Recriminations and countercharges have passed back and forth between the partners during the year, and ICDC brought its more than 700 workers back to Japan following the air raids. It's still unclear if construction will resume.

Iran still optimistically forecasts startup in 1982 of the main section of the complex, designed to produce aromatics (1.1 billion lb per year), ethylene (660 million lb), propylene (242 million lb), caustic soda (572 million lb), low-density polyethylene (220 million lb), high-density polyethylene (132 million lb), polypropylene (110 million lb), and styrene-butadiene rubber (88 million lb). It will be followed by plants for making dimethyl terephthalate (286 million lb), *p*-xylene (220 million lb), *o*-xylene (44 million lb), soda ash (264 million lb), triple superphosphate (220 million lb), and carbon black (35 million lb).

Saudi Arabia continues to be an island of relative stability in the troubled region. There, many U.S. and Japanese companies are lining up with Saudi Basic Industries Corp. (SABIC) to launch a variety of petrochemical ventures.

This past year, SABIC has signed contracts with Exxon, Mobil, Shell Oil, and a Japanese consortium that includes C. Ito, Mitsubishi Gas, and others. In addition, SABIC has entered into a partnership with Taiwan Fertilizer Co. Still in the discussion stage are projects with Celanese and Texas Eastern, Dow Chemical, and a second Japanese consortium headed by the Mitsubishi group of companies.

On the drawing board are four crackers with a total annual ethylene output capability of more than 4.52 billion lb. Plans also call for four plants for making low-density polyethylene, three for high-density polyethylene, and two each for ethylene glycol and methanol. In addition, there will be plants for making caustic soda, ethanol, ethylene dichloride, styrene, and urea.

According to Abdullah S. Nojaidi, SABIC's director of marketing, all these projects should be in place and running by 1985 or 1986. This in itself will constitute something of an engineering feat, considering the difficulties likely to be encountered in erecting and starting up sophisticated plants in a country where the climate is harsh and the engineering infrastructure is relatively undeveloped.

The complexes will be sited at two locations. The major concentration of plants will go in at Al Jubail, on the Persian Gulf, close to Saudi Arabia's oil and gas wells. There, the SABIC-Shell venture, Saudi Petrochemical, will be linked to a refinery Shell is building in partnership with Petromin, the Saudi state-owned oil and minerals organization.

Mobil's plants will be at Yanbu, some 730 miles west on the Red Sea. These, too, will be operated in conjunction with a 250,000 bbl-per-day refinery Mobil will build with Petromin.

Where and how the petrochemicals will be marketed are the cause of concern on the part of established producers, particularly those in Western Europe where the current overcapacity for petrochemicals is expected to continue for a number of years. From a logistics point of view, it is reasonable to assume that part of the output will be shipped to the Indian subcontinent and the Far East. But Shell, for one, makes no secret of its intention to bring some of its products to the U.S. And it is highly likely that Saudi chemicals also will be funneled into Western Europe.

Whereas most of the petrochemical plans of the Middle East stretch some years into the future, those of Qatar are a reality now. A few weeks ago, the first ethane cracker in the region started up there.

Owned by Qatar Petrochemical Corp. (QAPCO), in which France's CdF Chimie has a 16% stake (state-owned Qatar General Petroleum Corp. has the balance), the cracker at Umm Said has an annual ethylene output capability of 616 million lb. Some ethylene goes to QAPCO's neighboring 308 million lb-per-year low-density polyethylene plant, which came on stream in September.

And some may be fed to a 154 million lb-per-year high-density polyethylene plant being considered at the site. Ethylene not used at Umm Said will be exported.

The Middle East's chemical potential does not hinge on the region's massive oil and gas reserves alone, however. Israel's chemical industry, whose strong suit is inorganic chemicals, also is expanding ambitiously and plays a central role in the country's development programs. These programs focus on expansion of industries based on science and technology. Their goal is to increase exports to reduce Israel's massive trade deficit—$3.8 billion in 1979—and thus lessen its dependence on foreign loans and grants.

Implementation of these programs will not be easy, buffeted as Israel currently is by pressures from without and within, as well as an economy running triple-digit inflation rates for the past two years. But Israel's chemical industry already accounts for about a quarter of its total industrial production and almost a third of its exports (excluding processed diamonds in both cases).

Chemical-related exports reached $609 million in 1979, 29% of total output of $2.11 billion. (Exports were $774 million and output $3.75 billion if petroleum and related products are included.) In 1980, chemical exports are projected at $946 million. (If petroleum-related products are included, exports may exceed $1 billion for the first time, reaching $1.07 billion.) More than half the output of some chemical products is exported.

The target in the 1980's is a growth rate of 7 to 8% a year for production and 10 to 12% a year for exports. This would yield more than $7 billion in production and $3 billion in exports by the end of the decade.

Contributing to Israel's strong inorganic chemicals industry is the mineral wealth of the Dead Sea. Annual potash capacity there will be increased from its current 1.2 million metric tons of potassium chloride to 2.1 million metric tons by 1985.

Bromine production will be stepped up to 100,000 metric tons per year from 70,000. (Israel is second to the U.S. in world bromine production.) A new plant at Ramat Hovav, near Beersheba, can make 60,000 metric tons a year of bromine compounds for agriculture, industry, and flame retardant uses.

Another major mineral resource for Israel is the Negev phosphate deposits. Capacity, now 3 million metric tons a year, will be increased to 4 million by 1985. Israel also operates the world's largest potassium nitrate plant, recently expanded, which makes 220,000 metric tons per year, half the world's demand.

A plant under construction in Haifa will add 30,000 metric tons a year of chlorine and 35,000 metric tons of caustic soda to existing capacities of 70,000 and 75,000, respectively. A plant is being erected near Arad to make 120,000 metric tons a year of phosphoric acid.

Petrochemical production is focused on Haifa's oil refinery, where a recently completed major project centers on a 130,000 metric-ton-per-year ethylene plant. Included are a 60,000 metric-ton-per-year polyethylene plant, a 100,000 metric-ton-per-year vinyl chloride plant, a 65,000 metric-ton-per-year polyvinyl chloride plant, and an 180,000 metric-ton-per-year aromatics plant. Production of other downstream chemicals and plastics is planned.

Israel's pesticides—nearly two thirds of which are exported—are based almost exclusively on local R&D. Currently, about $100 million is being invested in further development, including plants to make five pesticides not at present made in Israel. The target is to increase exports to $250 million by 1983 ($182 million is projected this year).

Israel's exports are aimed mainly at West Europe and North America, aided by tariff-exemption agreements. The peace treaty with Egypt opens up for the first time the possibility of trade with one of Israel's Arab neighbors. Such trade is likely to be slow in developing, however, until political relations improve. □

Saudi Arabia's ambitious petrochemical plans start to take shape

Company name	Partners	Location	Products	Capacity, millions of lb/year	Projected startup	Status
Saudi Petrochemical Co.	SABIC, Shell Oil	Al Jubail	Ethylene Ethanol Ethylene dichloride Styrene Caustic soda	1443 618 999 649 781	1984–85	Contract signed, engineering by Fluor
—	SABIC, Dow Chemical	Al Jubail	Ethylene High-density polyethylene Low-density polyethylene Ethylene glycol	1100 231 154 660	1985	Under discussion, contract may be signed in early 1981
Al Jubail Petrochemical Co.	SABIC, Exxon	Al Jubail	Low-density polyethylene	528	1985	Contract signed
—	SABIC, Celanese/ Texas Eastern	Al Jubail	Methanol	440	1984	Under discussion, contract may be signed in early 1981
Saudi Methanol Co.	SABIC, Japanese consortium including C. Ito and Mitsubishi Gas	Al Jubail	Methanol	1320	1983	Contract signed
—	SABIC, Saudi Petrochemical Development Co.[a]	Al Jubail	Ethylene Ethylene glycol High-density polyethylene	990 330 198	1986	Under discussion, contract may be signed in early 1981
Saudi Yanbu Petrochemical Co.	SABIC, Mobil	Yanbu	Ethylene Ethylene glycol High-density polyethylene Low-density polyethylene	990 440 200 440	1985	Contract signed

a Includes 54 Japanese partners led by the Mitsubishi group of companies. **Source:** Saudi Basic Industries Corp. (SABIC)

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January 5, 1981

Lobbying missteps galvanized Senate on superfund Page 17

Albert C. Zettlemoyer
ACS President
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News of the Week

- ***Dow Chemical study of 2,4,5-T*** *and its contaminant dioxins shows no link between male employees' exposure to it and pregnancy outcomes of their wives.* ***Page 6***
- ***An electricity shortage in the U.S.*** *before 2000 is possible if all resources are not utilized, Electric Power Research Institute report cautions.* ***Page 6***
- ***EPA warns new Synthetic Fuels Corp.*** *that its plants must be designed and constructed to avoid toxic pollutant emissions, following EPA guidelines.* ***Page 7***
- ***Corco,*** *almost out of the bankruptcy slough after reaching agreement with most of its major creditors, now is negotiating for working capital.* ***Page 7***
- ***Space shuttle*** **Columbia** *will undergo testing next month in a dress rehearsal for its mid-March blastoff.* ***Page 7***

Business

- ***Rising U.S. chemical prices*** *not expected to survive under worsening business conditions; many chemicals due price increases may be substantially discounted.* ***Page 12***

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- ***Brazil aims at self-sufficiency in benzene*** *despite persistent benzene shortage; supply and demand may be balanced by 1983, according to one analysis.* ***Page 14***

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- ***Chemical industry's superfund lobbying backfires,*** *as law is passed to fund cleanup of chemical dumps and spills.* ***Page 17***

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- ***Soviet participation*** *at U.S. scientific meetings subject of White House memorandum expressing official U.S. policy.* ***Page 20***

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- ***NMR resolution is enhanced*** *by aligning protein crystals in a magnetic field in University of Illinois work.* ***Page 22***
- ***Synthetic membrane developed*** *to replace skin of burn victims consists of silicone elastomer bonded to polymer.* ***Page 23***

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- ***Prospects improve for biomass energy conversion*** *through Synthetic Fuels Corp., other federal energy projects.* ***Page 29***
- ***Reclaiming resin*** *from polyester beverage bottles is a fast-growing industry as more resin uses are developed.* ***Page 30***

Books

- ***Discoverer of LSD traces his career*** *in research on hallucinogens, claims they are valuable for psychotherapy.* ***Page 34***

Price increases not expected to stick

Worsening business conditions in the U.S. likely will result in substantial discounting for many chemicals due price increases this month

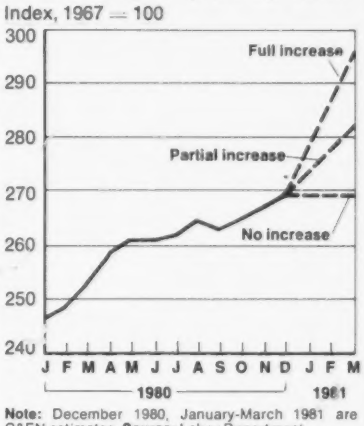
U.S. chemical prices are rising strongly again. No one doubts this as a general statement. But beyond this, there are plenty of questions on the durability and net financial effect of the increases. The answer seems to be, not too much.

Probably the most critical question is whether the multitude of price increases, due Jan. 1 or as soon as contracts permit, will stick. The expectation on the Gulf Coast is that the increase won't survive intact under worsening business conditions but that producers won't lose all of the posted gains either.

One rule of thumb for the organic product chain is that the strength of an increase is inversely proportional to the product's distance from raw material oil and natural gas. Among the inorganics, an analagous relationship to raw material sulfur seems the key.

Another important question on the increases is, oddly, why so small when raw material and other costs are rising so fast? Most officially announced increases are in the 5 to 15% range with a cluster from 8 to 10%. World oil prices already have risen much more than this and could go up again in the spring.

Chemical prices' slow pace of 1980 could pick up soon



Note: December 1980, January-March 1981 are C&EN estimates. **Source:** Labor Department

The answer is that producers are being realistic, given weakening business prospects this winter and their own sizable excess production capacity. Softening or falling demand means just one thing, downward pressure on prices, especially on price increases. The sea of extra capacity will tempt some producers into undercutting others.

A few of the most important examples show clearly the uninviting conditions surrounding prices this winter. Probably the most watched product is ethylene, head of the chain for a large number of organics and polymers. Faced with slumping demand last spring and summer, ethylene producers slashed fresh postings from the April level to 22.32 cents per lb from about 24.5 cents. This occurred even though some plants were shut down and others had their maintenance (nonproduction) periods greatly extended beyond the normal time.

Currently, ethylene's posted price is rising to about 26 cents a lb, possibly higher. However, not much later this month, most industry sources expect the actual selling price to settle down to about 24 cents. If this happens, the real increase will turn out to be about 8% instead of the apparent 17% increase.

With a deteriorating supply-demand situation on their hands, producers will argue inhouse whether they would lose more money on relatively high volume and low prices or on lower volume and higher prices. The answer for some may be to shut down units entirely rather than to try to run at low rates, if feedstocks increase in price.

For example, a cold winter could push up prices for light hydrocarbon feedstocks like propane and butane because of an increased tug from competing fuel uses. If chemical plants are already operating at less efficient low rates of capacity, the feedstock cost segment would become an unacceptably high fraction of total costs.

In much the same way, rising crude oil prices will increase the tab on chemical-bound refinery fractions such as gas oil (much like fuel oil). Gas oil and other heavy refinery-based feedstocks go into steam crackers producing basic olefins and aromatics. A further complication for steam crackers would occur if higher gasoline prices dampen gasoline demand and reduce operating rates at refineries. This would hold down the value of one competing fuel use of chemical feedstocks but might increase another if fuel oil supply is crimped.

Propylene's price outlook generally will follow ethylene's as it has in the past. Both materials' major use, polymers, faces the same relatively weak supply-demand picture this quarter.

An exception among the major

As 1981 opens, not all prices are back to mid-1980 levels

	Typical contract or posted price Jan. 1, 1981	July 1, 1980	% change
Ethylene	26 cents/lb	24 cents/lb	+8%
Propylene (polymer grade)	22.5 cents/lb	21 cents/lb	+7
Butadiene	36 cents/lb	32 cents/lb	+13
Benzene	$1.80/gal	$1.55/gal	+16
Styrene	39 cents/lb	35.8 cents/lb	+9
Vinyl chloride	19 cents/lb	22 cents/lb	−14
Polyethylene, low-density	41 cents/lb	42.5 cents/lb	−4
Polypropylene	41 cents/lb	47 cents/lb	−13
Sulfuric acid[a]	$82–$85/ton	$57–$60/ton	+43
Caustic soda[b]	$210–$220/ton	$150–$180/ton	+42

a Gulf Coast prices. b Gulf Coast prices, 50% regular grade

olefins seems to be butadiene. Because butadiene production is now dominated by steam cracking operations, which produce it as a coproduct, its output parallels ethylene with a slight skewing for different feedstocks. With the resulting limited output apparently in store for the first quarter, butadiene supply will be much closer to demand than for other olefins.

Demand for butadiene, because of low inventories in end-use rubber and tires, is expected strong enough that the posted price of 36 cents a lb likely will hold through the first quarter. The price then could strengthen if business improves in the auto industry later in the year.

Among leading aromatics, benzene also is expected to hold close to the new posted price of about $1.80 per gal. The large spot market for benzene may shade the posted price a few cents. However, industry opinion is that crude oil costs and the like will not allow much cutting below this level because of narrow profit margins.

The chance is also considered remote that the price of an additional benzene raw material, toluene, will fall low enough on the spot market to stimulate additional benzene production by reactivating idle hydrodealkylation units. Toluene price likely will hold up because of its steady demand in unleaded gasoline.

Down the product chain from these basic olefins and aromatics, some intermediates may get into a cost-price squeeze. Hit by substantial raw material cost increases, these products may not be able to pass them along in proportionate price increases because of weak polymer markets.

A good example is styrene, which is made with both benzene and ethylene. Styrene prices are up less than average for basic chemicals and certainly less than the percentage increase in benzene. Prices for styrene-based polymers are rising, too, but only to levels from which they fell from early summer 1980. In other words, the value of styrene's feedstocks has forged ahead while the value of styrene's derivatives is just catching up. The net effect is a cost-price squeeze.

Polymers generally are weaker pricewise than are basic petrochemicals. Polymers are getting price increases this winter, which are expected to hold up partially. But after polymers' price slump since last spring, many are not selling close to levels of a year ago.

CHECKOFF

NEW PLANTS

■ **Acetyl chloride.** American Hoechst plans to build unit at its Baton Rouge, La., plant with capacity of 4 million lb a year for this pharmaceutical raw material. Startup is set for second-half 1982, and technology will be from the parent Hoechst of West Germany.

■ **Ammonia.** Hawkeye Chemical subsidiary of Getty Oil plans to spend about $24 million to raise capacity at Clinton, Iowa, more than 50% to 220,000 tons per year; completion scheduled for April 1982. Fluor will handle project.

■ **Fluorocarbon 22.** Du Pont plans to expand companywide capacity for this material, used in fluoropolymers and refrigerants, 35% through modification of production facilities at Montague, Mich.; new capacity to start up in early 1982.

■ **Hydrochloric acid.** Vulcan Materials plans to spend $5 million for unit at its Port Edwards, Wis., plant with capacity of 250 tons a day of this industrial acid; construction to start this spring with completion scheduled for November 1981.

■ **Plastics additives.** Witco Chemical plans to expand its Argus division plant at Taft, La., doubling undisclosed capacity for methyltin stabilizers and adding unspecified capacity to make antimony stabilizers; $1.5 million project to be completed in fourth quarter 1981.

PLANTS COMPLETED

■ **Nitrocellulose.** Hercules has completed expansion of its Parlin, N.J., plant to increase production of this resin 50% to unspecified level.

■ **Phenol.** Georgia-Pacific has added 70 million lb per year of capacity at Plaquemine, La., bringing total capacity to 330 million lb; product yield from cumene now improved 10%.

■ **Specialties.** Sybron's chemical division has completed unit at Wellford, S.C., for various grades of isopropylbiphenyl and high-purity biphenyl; unit replaces old facility at Lyndhurst, N.J., but capacities not disclosed.

Low-density polyethylene, the leading polymer, is expected to settle out to a price about 10% less than its latest 41 cents-a-lb posting, or about 37 cents for the lowest-cost grade. Even last summer, this polyethylene had a list price of 42.5 cents.

Polypropylene is even worse off, with a contract price of 41 cents a lb, far below the 47-cent contract level of last summer. The actual selling price this winter could come out about 39 cents.

Polyvinyl chloride, whose lower-cost grades had some of the biggest price cuts in 1980, is expected to recover somewhat, but later in 1981. Sagging markets in housing and other construction will hold up progress until after the first quarter. Indicative of its pricing is that the common monomer for vinyl plastics, vinyl chloride, has a posted price of 19 cents a lb, 3 cents below last summer's price.

Poor fortunes in PVC work back to hit the raw material chlor-alkalies business. Under weak demand in other derivatives, too, chlorine producers are holding down plant operating rates. The result is that coproduct caustic soda has become one of the few chemicals in short supply. This has driven up posted caustic prices more than 40% in the past six months to $210 to $220 per ton. Further increases are the prospect until the chlorine market improves enough to increase caustic supply.

Similarly, a tightness in world sulfur supplies has led to price increases in sulfuric acid fractionally about the same as for caustic soda. This is putting the heat on prices for phosphate fertilizer, which is having none too good a year.

In sum, with the exception of sulfuric acid, caustic, and a few other chemicals, producers will have to work hard just to keep part of their price increases this winter. Later, when an improving market allows, chemicals will have a lot of upward price pressure built in ready to release.

Bruce Greek, Houston

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- ***Most scientific and engineering societies*** *have not adopted codes of ethics.* ***Page 6***
- ***Mice were not cloned,*** *despite reports in news media; work involved nuclear transplant manipulations of mouse cells.* ***Page 7***
- ***U.S. chemical industry*** *remains a leader among energy-intensive industries in conserving energy use.* ***Page 7***
- ***Nobelist Harold Urey,*** *discoverer of deuterium, is dead at 86.* ***Page 8***
- ***AAAS hires adviser,*** *plans programs to attempt to halt the decline in U.S. science and engineering education.* ***Page 8***

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- **Chemical Abstracts'** ***new patent index*** *enables searcher to find data on all issued documents on an invention.* ***Page 31***

Preliminary Program

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For its survey, the project defined "ethics" as "those rules that are intended to define the rights *and* responsibilities of scientists and engineers in their relationship with each other and with other parties including employers, research subjects, clients, students, etc."

Of more than 170 AAAS-affiliated societies responding to the survey, 46, or about 30%, have adopted their own ethical rules of conduct, most commonly in the form of codes of ethics. About half represent social and behavioral sciences and medicine and health sciences.

Less than half the societies reported that they had sanction procedures available to enforce their ethical rules. An informal reprimand is the most frequently applied sanction.

The report highlights selected ethics activities from 13 societies including excerpts from ethical codes and procedures for investigating complaints. Included is the American Chemical Society's "Professional Employment Guidelines."

Among its recommendations, the project suggests that societies distinguish between broadly defined ethical principles and more narrowly prescribed rules of conduct in their formal ethics statements. Indeed, on the basis of survey replies, the working definition of ethics had to be modified by changing "principles" to "rules."

The report notes that, increasingly, the professions and the public have become aware of the ethical concerns associated with the development and use of science and technology. This, in turn, has prompted a widespread re-examination of the present status of professional self-regulation and has stimulated interests in the ethics activities of the professional scientific and technical societies. □

Misleading cloning reports circulated

Misleading reports about the first cloning of mice were widely circulated last week. Those reports revolved around research of Karl Illmensee and his colleagues at the University of Geneva in Switzerland in collaboration with Peter Hoppe at Jackson Laboratory in Bar Harbor, Me. Their research is now being published in the journal *Cell*, but was made public at scientific meetings at least 18 months ago (C&EN, July 30, 1979, page 19).

The research of Illmensee and Hoppe is best described as nuclear transplant manipulations of mouse cells. Those manipulations are skillful, and they represent significant progress toward understanding how mammalian cells work. However, they do fall short of being outright cloning, which would involve producing mature mice from a single cell of another mature mouse. The scientists doing the nuclear transplantation research have not claimed success at mouse cloning; it is just that accounts of their research have been misinterpreted.

The actual experiments start with mouse cells obtained from early embryos, called blastocysts, having a total of 64 cells. One such cell is injected into a fertilized egg cell, obtained from a genetically distinct mouse. The technique for the injection is painstaking, and Illmensee has developed delicate procedures to prepare the recipient egg cell properly. Afterward, the sperm and egg nuclei are removed from the recipient cell, leaving only the transplanted nucleus that had been obtained from the embryonic cell.

Next, that newly amalgamated cell is implanted in the uterus of another mouse, a foster mother of yet another genetic makeup. In a very few cases so far, such an egg cell has developed more or less normally into a mouse. Genetically and biochemically, such mice (there have been at least three) display the properties derived from the embryo cell nucleus, indicating the success of the transplant. The mice produced this way do not have the genetic makeup of either the mouse that supplied the egg cell (used to receive that nucleus) or the foster mother.

Illmensee has said that such experiments ought not to be undertaken in man, and that their value resides in what can be learned about normal and abnormal cell development. □

Industry continues to cut energy demand

The U.S.'s 10 most energy-intensive industries are continuing to reduce their energy demand, with the chemical industry emerging as a leader in industrial energy conservation, says the Department of Energy in a report to Congress.

The chemical industry is one of the largest consumers of energy among U.S. industries. In 1979 the 171 chemical companies reporting to DOE through the Chemical Manufacturers Association used a total of more than 3.8 quadrillion Btu of oil, natural gas, electricity, and other fuels, excluding feedstocks. But the chemical industry's successful push for energy conservation is illustrated by its total energy consumption rising only 3.37% since 1972, while production output increased almost 28%.

The other industry sectors are not doing so well as the chemical industry, but all are successfully conserving, DOE says. The absolute level of energy consumption by the 10 industries has fallen 2.25% since 1972; at the same time output in manufacturing industries has risen more than 17%. Total energy savings amounted to 2.2 quadrillion Btu per year. In other words, the reporting industries would have consumed an additional 1 million bbl of oil per day to achieve their 1979 product output if they were still operating at 1972 levels of energy efficiency.

Companies in the reporting industries have reduced their natural gas consumption 14% since 1972 and residual oil use has declined almost 5%, the result of an evident trend toward more reliance on electricity. However, there is no indication, DOE says, of any emerging trend toward direct substitution of coal for primary fuels.

Although progress has been made, DOE warns that industrial energy conservation is at a turning point. The industry sector now uses about 37% of the nation's total energy and could be using 50% by 1990. To offset

Chemical industry has exceeded energy goals, increased output

	Energy savings[a]		
	1979 actual	1980 target	Change in output[b]
Machinery, except electrical	24.7%	15%	34.3%
Transportation equipment	23.4	16	−26.6
Chemicals and allied products	22.1	14	34.3
Fabricated metal products	21.5	24	8.2
Textile mill products	17.7	22	19.8
Paper and allied products	16.9	20	26.6
Food and kindred products	15.3	12	23.7
Petroleum and coal products	14.7	12	36.6
Stone, clay, and glass products	12.9	16	20.6
Primary metals	7.8	9	−9.0

a Reduction in energy demand per unit of output based on 1972 efficiencies. b Compared to 1972 levels.

this growth in demand, industry would have to install at least the best available energy conservation technologies, which could increase energy efficiency 20 to 30%.

But adoption of these technologies would require major capital investments, something DOE thinks is unlikely to happen. Energy costs still comprise only 2 to 8% of the operational costs of most energy-intensive industries. Since energy is not a major cost, energy conservation investments often receive relatively low priority in comparison to competing capital investment needs. That situation is likely to continue, DOE says, since only a few industrial sectors—such as chemicals, petroleum, and transportation equipment--are in a position to invest significant capital in energy conservation. □

Harold Urey dead at 86

The Nobel Prize has come to many scientists late in their careers when their creative juices were drying up, their most fertile years behind them. But Harold Clayton Urey's 1934 Nobel Prize in Chemistry for his discovery of deuterium came early, presaging a long and fruitful career. Last week, that career ended when Urey, 86, died at his home in La Jolla, Calif.

Urey's inquisitive mind ranged over both the atomic and the astronomical realms, often harking back through time to the first stirrings of life on Earth, or to the birth of the solar system.

But his single most notable discovery, made at Columbia University with George M. Murphy and Ferdinand G. Brickwedde, was deuterium. Urey had predicted that the residue from the distillation of liquid hydrogen should contain the heavy isotope. He was proved right in 1931, just eight years after receiving his Ph.D. in physical chemistry from the University of California, Berkeley. The discovery led to the development of the hydrogen bomb. It also may prove to be the basis for unlimited energy from fusion.

Harold Urey

After this early triumph, Urey developed methods for separating the heavy isotopes of other elements. During World War II, the group he directed at the top-secret Manhattan Project facilitated the separation of uranium isotopes by gaseous diffusion. This work opened the door to the atomic bomb.

After the war, after seeing his efforts channeled into what he regretfully called "a terrible weapon," Urey moved to the University of Chicago. There, he pursued more philosophically agreeable projects, such as studying the origin of the planets, and chemical evolution on Earth. Urey believed that the planets formed initially as cold, rather than molten, bodies. And his classic experiment with Stanley Miller showed that amino acids could form from simple gases thought to have been present in Earth's early atmosphere. Urey also developed an isotopic method that he used to determine ocean temperatures in past geologic ages.

In 1958, Urey joined the University of California, San Diego. With the advent of the age of planetary exploration, he enthusiastically became involved in the study of the moon rocks brought back by the Apollo missions. He also was a consultant on the Viking missions to Mars.

In the past few years, a progressively worsening heart condition began to take its toll on Urey, an irrepressible man who cultivated orchids in his garden and gazed longingly at the moon. □

AAAS acts to halt decline in science education

A series of actions designed to help in arresting a serious decline in U.S. science and engineering education is being undertaken by the American Association for the Advancement of Science.

F. James Rutherford, assistant secretary of the U.S. Department of Education, will join AAAS after Jan. 20 as adviser on science education to the AAAS board of directors. In addition, the board has passed a resolution setting in motion initiatives that are part of an effort to make science and engineering education, and general scientific literacy, central concerns of AAAS in the 1980's.

"The U.S. is working itself into a real jam" in science and engineering education, observed AAAS president Frederick Mosteller of Harvard's school of public health, in announcing the actions.

The moves, announced last week in Toronto at the AAAS annual meeting, are a response to growing evidence that, for the past 15 years, there has been a shrinking of commitment in the U.S. to excellence in science, mathematics, and engineering. A report prepared last fall for the White House by the National Science Foundation and the Department of Education made a case for such a decline, particularly in regard to the scientific literacy of the general population (C&EN, Nov. 10, 1980, page 37).

AAAS president-elect, Yale physicist D. Allan Bromley, notes that it's difficult to quantify the poor performance. But, he says, there is an anecdotal uniformity across the country to suggest the problem is severe. AAAS won't be able to redress the problem, he says, but hopes to have a substantial impact.

Rutherford, who was formerly assistant director for science education at NSF, will be helping the AAAS board to plan programs to combat the problem. The resolution passed by the board, among other things, directs the AAAS president to "convene a consultative conference of heads of affiliated societies to appraise the health and priority needs of science and engineering education in the U.S. in the 1980's." The American Chemical Society is one of more than 240 affiliated societies and academies of science.

Also, the resolution directs that a major theme of the 1982 annual meeting of AAAS in Washington, D.C., be "Toward a National Commitment to Educational Excellence in Science and Engineering for All Americans." In addition, Mosteller says, AAAS plans to use its new magazine designed for the general public, *Science 81*, to create teaching materials to help science teachers in secondary schools, and especially benefit minority students and young women. □

NOTE

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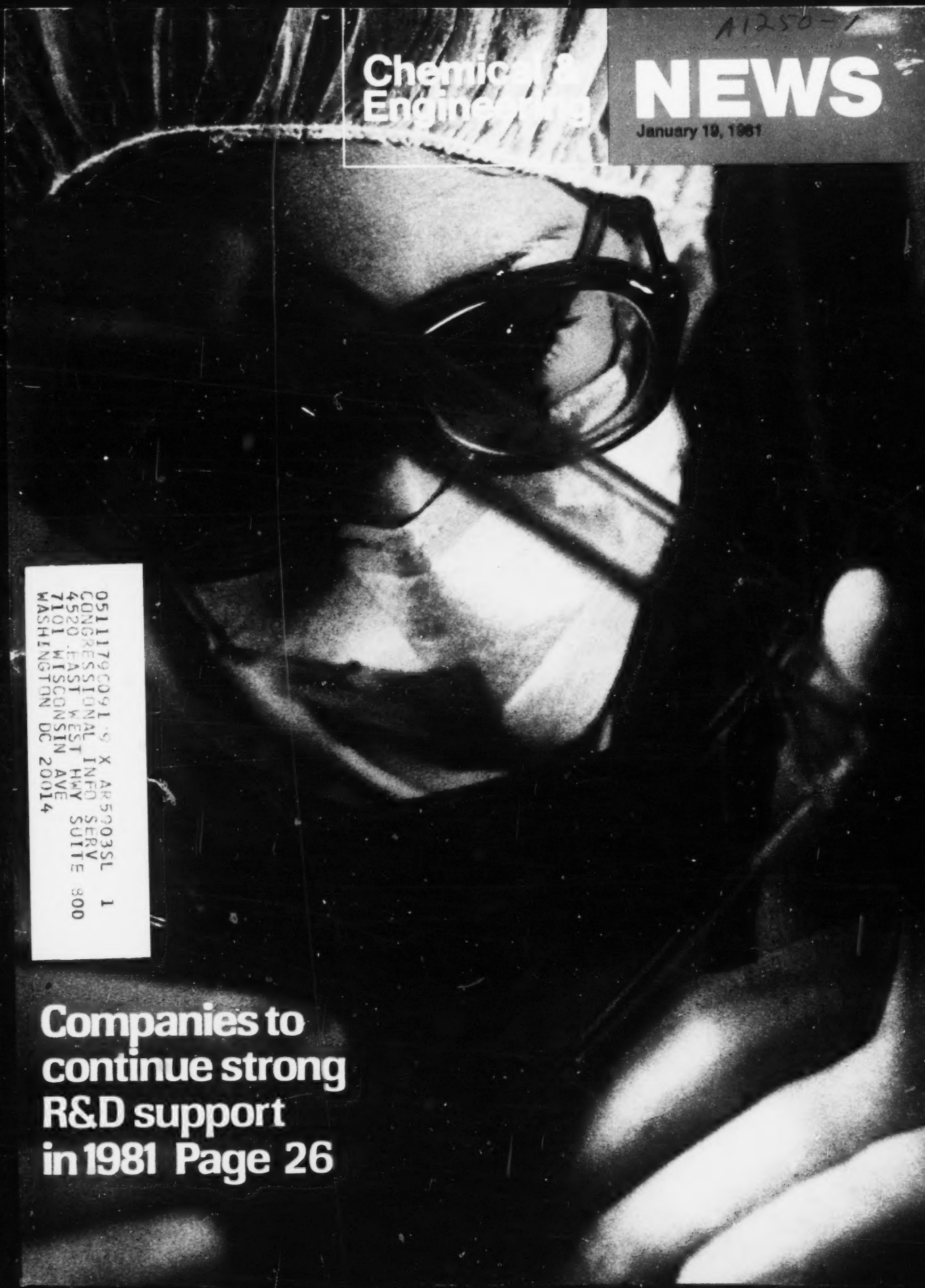
Chemical & Engineering

NEWS

January 19, 1981



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- ***Major future environmental issues*** *highlighted in CEQ reports.* ***Page 10***
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R&D support continues strong in 1981

Following 18% increase in 1980, R&D budgets at largest U.S. chemical firms are headed up 14% this year; job prospects stay bright

William F. Fallwell
C&EN, New York

Funding for research and development at the leading U.S. basic chemical companies came out even higher than expected in 1980, despite the recession. And prospects look just as bright in 1981. In both years, R&D support is beating R&D inflation, indicating a continued brisk job market for scientists and engineers in the industry.

C&EN's annual survey of R&D spending plans by 15 leading basic chemical companies shows an expected 14% gain in 1981 over 1980. Combined budgets this year will surpass $2 billion for the first time, reaching an estimated $2.16 billion. This means a doubling of R&D spending since 1974, when the industry first reached $1 billion.

In 1980, R&D spending exceeded early estimates, running up 18% over 1979 to reach $1.89 billion. A survey a year ago indicated an expected gain of 13% (C&EN, Jan. 21, 1980, page 12). Hence, R&D managers proved for the second recession in a row that they could make good on their general goal of keeping R&D support independent of recessionary earnings fluctuations.

The double-digit R&D budget gains in 1980 and 1981 are keeping safely ahead of R&D inflation. According to Dr. W. Halder Fisher of Battelle Columbus Laboratories, the U.S. industrial R&D inflation rate (the increase in cost per technical employee in R&D) is heading up to 9.1% in 1981 after a surprisingly low 6.3% in 1980.

The low 1980 inflation percentage may not be too hard to rationalize, since salary increases for all but brand-new chemists rose just 4 to 8% in 1980, according to C&EN's latest employment outlook survey (C&EN, Oct. 20, 1980, page 67). Such salaries take at least half of companies' R&D funding.

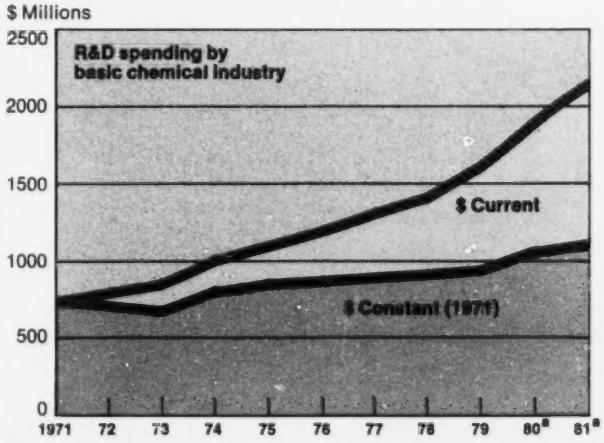
As a result, constant-dollar R&D support in the chemical industry rose 12% in 1980 and is due up another 5% in initial estimates for 1981. The 1980 increase is tied for the largest since the mid-1960's.

Constant-dollar chemical industry R&D support is now more than 50% higher than at its cyclical low point in 1973. By 1982, current-dollar R&D budgets may easily triple from 1971.

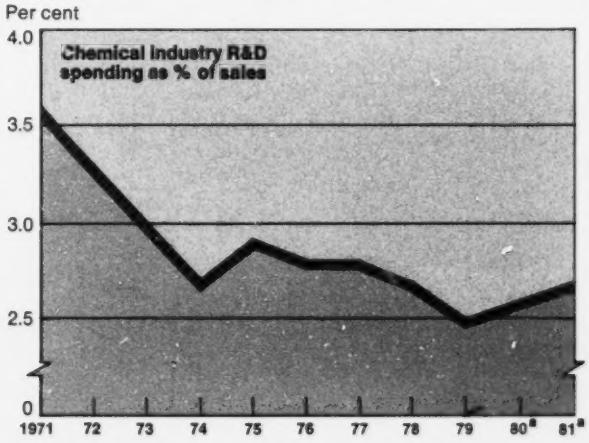
The influence of figures like these on R&D employment is not hard to imagine. Demand for chemists, chemical engineers, and most other kinds of technical professionals working in R&D at basic chemical companies stayed very high through the 1980 recession. True to form, R&D staffing followed the trend in constant-dollar R&D support. In C&EN's latest employment outlook review, a net increase to R&D staffs of 3% was expected in 1981 after a 3% rise in 1980. These rates are ahead of the steady 2% annual staff increases from 1975 through 1979.

Such vigor in R&D is leading to back-to-back yearly gains for R&D spending by basic chemical companies as a per cent of sales. From a low of 2.5% in 1979, R&D spending's per cent of sales rose to 2.6% in 1980 and could reach 2.7% in 1981. Such an upswing, even if statistically small, runs contrary to the trend through the past decade. It is difficult for R&D budgets to keep up percentagewise with gains in chemical sales when the inflation rate of chemical raw materials greatly outpaces the inflation rate in R&D operations, influenced most by salaries.

R&D budgets for 1981 once again will beat inflation at chemical firms...



...and will have a good chance to rise as a percentage of sales



a Estimates. **Sources:** C&EN survey, Battelle Columbus Laboratories

Du Pont becomes first U.S. chemical company with R&D budget of more than $500 million

$ Millions	Worldwide R&D spending: Planned 1981	Actual 1980	Planned 1980[a]	1979	1978	1977	1976	1975	Change from previous year: 1981	1980	R&D spending as % of sales: 1980	1979
Air Products	$ 32	$ 30	$ 27	$ 23	$ 23	$ 24	$ 19	$ 16	7%	30%	2.1%	1.9%
Akzona	33	28	27	25	23	20	18	17	18	12	2.6	2.5
Allied Chemical	137	105	75	70	56	51	40	35	30	50	1.8	1.6
American Cyanamid	160	140	140	124	108	96	83	73	14	13	4.0	3.9
Celanese	110[b]	100[b]	100	92	83	77	70	64	10	9	3.1	2.9
Diamond Shamrock	60	49	50	42	36	29	24	20	22	17	1.5	1.8
Dow Chemical	370	321	310[b]	269	232	203	188	167	15	19	3.0	2.9
Du Pont	535	485	480	415	377	367	353	336	10	17	3.6	3.3
W. R. Grace	54	46	50	46	41	34	30	30	17	0	0.8	0.9
Hercules	57	53	53	47	40	37	35	30	8	13	2.1	2.0
Monsanto	260	225	195	174	144	132	114	116	16	29	3.4	2.8
Pennwalt	28	25	25	24	23	21	19	16	12	4	2.1	2.2
Rohm & Haas	73	65	62	54	49	45	43	45[c]	12	20	3.8	3.4
Stauffer Chemical	52	45	45	37	34	33	29	24	16	22	2.7	2.4
Union Carbide	188	170	174	161	156	156	142	120	11	6	1.7	1.8
TOTAL	$2149	$1887	$1813	$1603	$1425	$1325	$1207	$1109			2.6%	2.4%
ANNUAL CHANGE	14%	18%	13%	12%	8%	10%	9%	12%				

a Earliest company estimate. b C&EN estimate. c Includes budgeting later deleted.

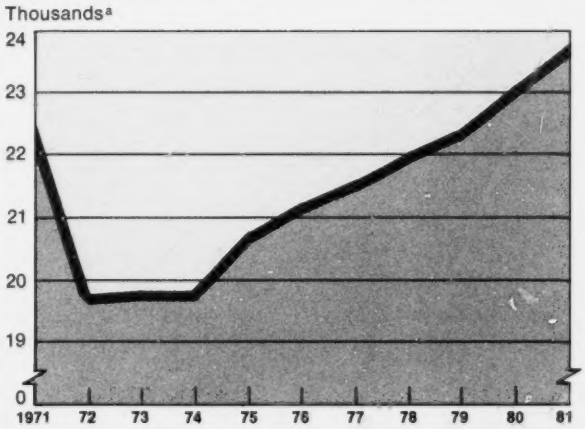
In fact, the very moderation in R&D inflation may help keep it in boardroom favor. Even without such consideration, R&D enjoys a level of top management pleasure not seen since the mid-1960's. The big push in the mid-1970's to clean up industrial chemical processes and to make them more efficient was a major factor in restoring R&D to corporate grace.

However, at present, a corporate desire to find breakaway products based on new chemical science underlies much of the current gains in R&D support. It is taking big money to open up the fields of genetic engineering and other approaches leading to new-generation agricultural chemicals, new drugs, and other high-value specialties R&D managers think will be the key to corporate profits later in the 1980's.

Specific company plans show some large R&D budget increases in both big and small companies. At the head of the pack is Du Pont, continuing its newfound push in pioneer and applied R&D with a planned 10% increase in 1981 after a 17% gain in 1980. Performing nearly one fourth of all basic chemical industry R&D, Du Pont will be the first to pass $500 million in annual funding. As a per cent of sales, R&D budgeting at Du Pont once again is climbing to reach about 3.6% in 1980, well over the industry average.

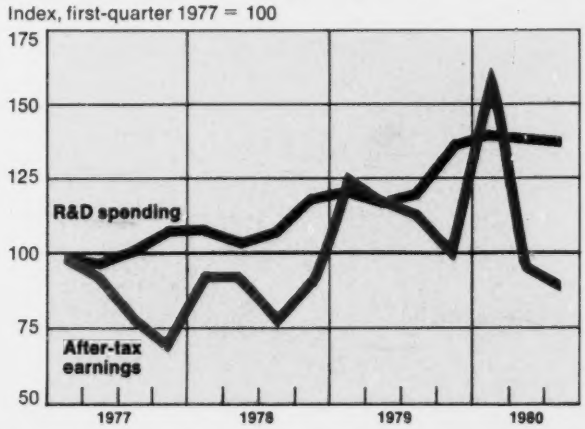
However, Du Pont is no longer very far ahead of the second largest U.S. chemical R&D establishment at Dow Chemical. Dow's formal R&D budget in 1981 will head up another 15% to $370 million. However, additional funds for R&D at its pending ethical drug acquisition from Richardson-

Ranks of scientists, engineers in chemical R&D will continue to grow in 1981...

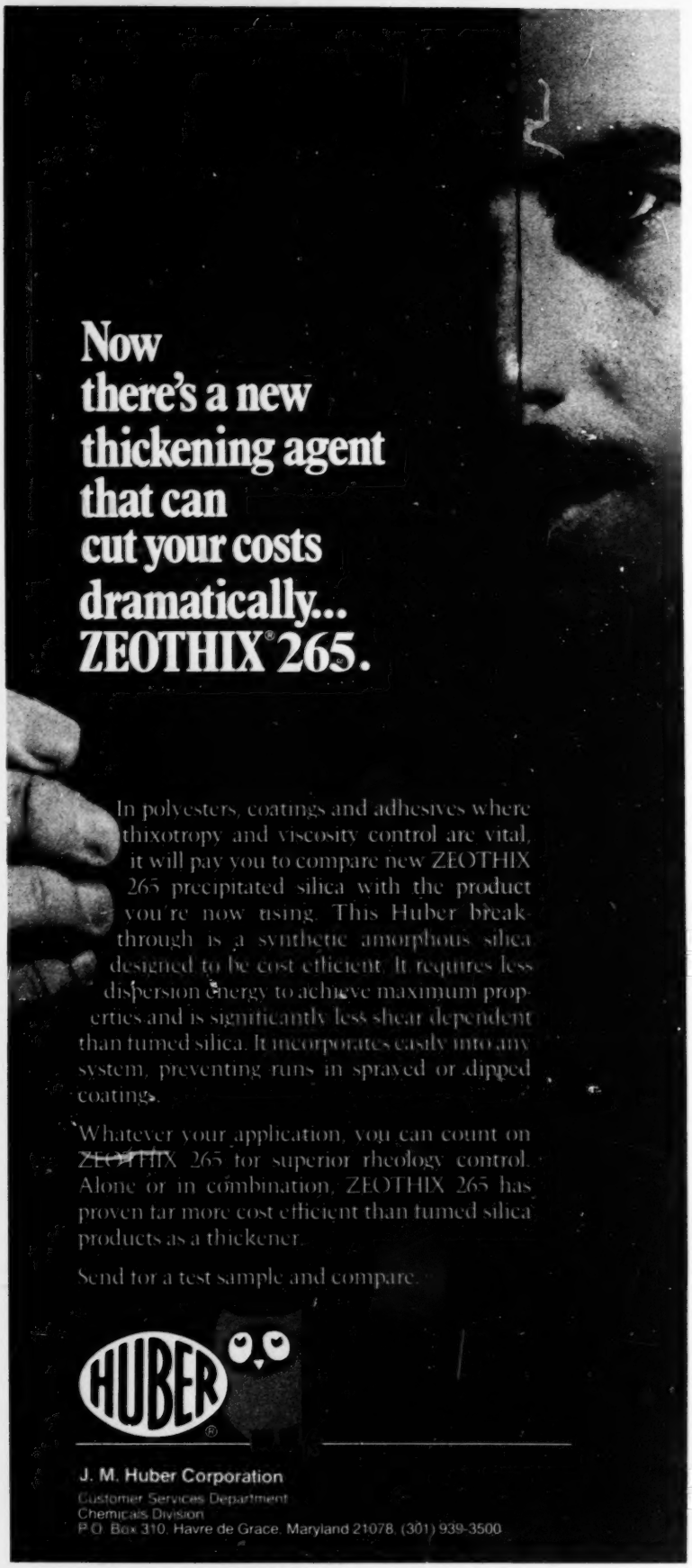


a Full-time equivalent R&D scientists and engineers in basic chemical industry at beginning of year. **Sources:** National Science Foundation, C&EN survey

...supported by funding clearly shielded from earnings flip-flops



Source: Combined data from American Cyanamid, Celanese, Diamond Shamrock, Dow Chemical, Monsanto, Stauffer Chemical, and Union Carbide



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Merrell could easily put Dow over $400 million this year.

Other sizable R&D increases in 1981 include a 16% rise at Monsanto, 18% at Akzona, 22% at Diamond Shamrock, and 30% at Allied Chemical. Allied is really on the move in R&D, with a budget expected to reach about $137 million in 1981 after a protracted history close to $30 million a decade and more ago. □

Processes spur interest in making amino acids

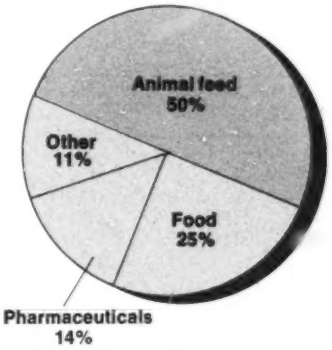
New technologies are causing chemical companies to take a new look at amino acid production in light of increasing demand, according to a study of the amino acid market by Eldib Engineering & Research of Berkeley Heights, N.J. According to the Eldib study, worldwide market demand for amino acids in 1979 was valued at about $1.3 billion. This is expected to increase more than 90% to $2.5 billion by 1986, with an average annual growth rate of about 9.8%.

In the U.S., the market for amino acids totaled about $220 million in 1979. According to the study, the major market is in the supplementation of swine and poultry feeds. This use amounted to 50% of the total market, or $110 million.

The second largest market is for use in foods, with an estimated value of about $55 million. Glutamic acid as monosodium glutamate dominates this use.

Amino acids used in infusion solu-

Animal feeds make up half of amino acids demand



Total U.S. market, 1979 = $220 million

Source: Eldib Engineering & Research

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n-Octyl mercaptan
tert-Octyl mercaptan
tert-Nonyl mercaptan
n-Dodecyl mercaptan
tert-Dodecyl mercaptan
tert-Tertradecyl mercaptan
tert-Mixed mercaptan
(C_{12}, C_{14}, C_{16})
2-Mercaptoethanol
Benzyl mercaptan

Sulfides
Ethylthioethanol
Di-n-butyl sulfide
Di-tert-butyl sulfide
Ethylthioacetate
Phenylthioethanol

Disulfides
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tions, therapeutics, and pharmaceuticals were valued at about $30 million in 1979. Another category—cosmetics, special and reducing diets, and other miscellaneous applications—had an estimated market value of $25 million in 1979.

I. A. Eldib, president of Eldib Engineering, forecasts about 11% annual growth for amino acids in the U.S. This will be led by L-lysine, followed by glycine. Demand for lysine is expected to double by 1985. According to the study, this growth will be fueled in part by the emergence of distillers dried grains as an animal feed. Distillers dried grains, which are byproducts of ethanol production, are deficient in lysine.

The U.S. will have to hurry to catch up with other parts of the world in amino acids production, however. Currently, most of the amino acids used in the U.S. are imported from Western Europe and Japan.

Eldib says that production of amino acids is again being considered in the U.S. because of the steadily rising costs of imports. New process opportunities may overcome barriers that previously have been encountered in considering U.S. production.

Chief among these new technologies is recombinant DNA. The study recommends that the approach to amino acid production in the future would be to use DNA technology to construct new bacterial strains in which the genes that direct the synthesis of amino acids can be amplified up to a hundred times and beyond. This could result in very high yields when adapted to fermentation.

Eldib holds very little hope for the use of standard fermentation processes in the U.S. According to him, the fermentation processes require a knowledge that is just not available in this country. "We just don't know enough and therefore cannot compete with the Japanese," he says. Further, according to Eldib, the Japanese will not license their technology. But, he says, if the U.S. uses recombinant DNA technology to catch up, it will have great probabilities of success.

The production of amino acids for pharmaceutical grades may require another process, Eldib believes. He says that already in existence, but overlooked by all but a few producers, is chromatographic fractionation of amino acids from hydrolyzed proteins. Eldib engineers consider this technique to be the most practical route today to build a high-value amino acids industry in the U.S. for pharmaceutical grades. □

Strong growth ahead for industrial enzymes

Survey predicts global annual growth on average of at least 8% from 1979 to 1985, puts market by mid-decade at $500 million to $600 million

Demand for industrial enzymes is buoyant, and prospects in the near term are bright. In 1985, the global market might be just about twice 1979's $300 million total.

A somewhat more conservative estimate puts the 1985 figure close to $500 million. But even so, that would represent an average annual growth rate of more than 8% over the six-year span. Such an outlook is all the more encouraging when put against the generally depressed state of the global industrial chemicals business and the dubious prospects for expanded markets.

These facts emerged from a just completed survey undertaken by Leo Hepner and Celia Male at L. Hepner & Associates of London. "The projection can be taken as a certainty based on the demand pattern," Hepner maintains. "It is not mere conjecture."

The survey results, titled "Industrial Enzymes, Market Opportunities in the U.S. and Western Europe, 1980–1985," is the third that Hepner has undertaken in the field. "The spur for doing the studies has been the erroneous estimates of industrial enzyme markets that appear from time to time," he says. He points out that many commentators tend to exaggerate certain areas of the business while missing others.

Hepner confined the study to bulk industrial enzymes. These usually have a relatively low content of pure enzyme protein, from 1 to 3% or so of total product weight. Not included are specialty enzyme preparations that can have up to 100% of pure enzyme proteins. They are much more costly and are used largely in diagnostic aids, biochemical analyses, specialty pharmaceutical applications, and the like.

The market for industrial enzymes in Western Europe runs ahead of that

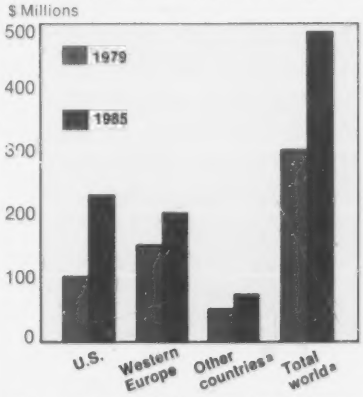
C&EN staff photo

Hepner: forecast not mere conjecture

in the U.S. In 1979, the most recent year for which confident data are available, the European value was about $150 million, or 50% of the world total. That's half again as much as the $100 million in U.S. sales. Other countries combined accounted for the $50 million or so balance.

The Hepner study excludes the communist bloc countries. And the Japanese market was not included because, according to Hepner, this is of minor significance compared to Western Europe and the U.S. The main outlets for enzymes in Japan are in pharmaceutical applications.

Markets for industrial enzymes are increasing



a Excluding communist bloc countries and Japan.
Source: L. Hepner & Associates

The situation will change in 1985. Then, the market in Western Europe will be about $200 million, close to 40% of the conservative world estimates that year. On the other hand, U.S. sales likely will reach $220 million. Elsewhere sales could total $70 million.

If the projection materializes, it will mean that industrial enzyme demand in the U.S. will grow an average of 14% annually between 1979 and 1985. In Western Europe, the growth will be 5% per year or so. For the rest of the world, annual growth will be closer to 6%.

Two developments in particular will provide the springboard for faster anticipated U.S. growth in the years ahead, Hepner believes. One will be greater call for sweeteners derived from cornstarch. The other will be the surge in demand for gasohol, a mixture of ethanol and gasoline.

A number of interesting facts emerge from the Hepner survey. One is that only eight companies are responsible for about 90% of the global industrial enzyme output. Another is the dominance of European concerns in the field. Five of the eight are based in Western Europe. In the U.S., Miles Laboratories, itself a subsidiary of West Germany's Bayer, is a leading producer. Several large U.S. chemical and pharmaceutical makers, such as Pfizer, Rohm & Haas, and Universal Foods, have a minor involvement in enzymes.

By far the two largest companies involved are Gist-Brocades, headquartered in Delft, the Netherlands, and Novo Industri, based in Copenhagen, Denmark. Between them, they control more than 60% of the business.

"All together, 16 enzymes account for 99% of the entire bulk market," Hepner and Male point out. These fall into three broad classes. Amylolytic enzymes break down carbohydrates. Proteolytic enzymes act on proteins. And a miscellaneous group includes enzymes that bring about oxidation, isomerization, etc., of a substrate.

Of course, enzymes have been harnessed for industrial processes for centuries. All were extracted origi-

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From: The Project Manager

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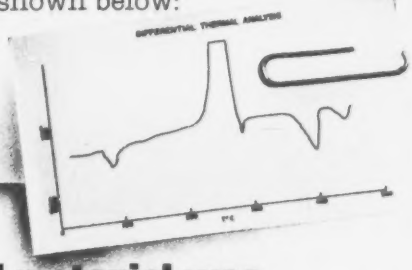
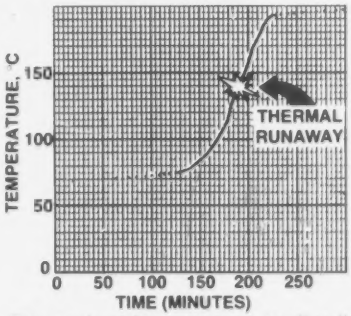


DTA: implied material was thermally stable below 220° C. ARC™: revealed thermal instability at 70° C.

In this example the DTA measured exothermic decomposition, beginning at 220°C. The analyst might conclude that the chemical decomposes at 220°C and would be thermally safe at some temperature below 220°C. In contrast the ARC™ (Accelerating Rate Calorimeter) measured thermal instability to as low as 70°C. The chemical is decomposing and initiating a thermal runaway reaction.

ARC™ ANALYSIS



This exothermic reaction can be described by the time-temperature relationships of kinetics. Most chemicals decompose over a large temperature range and the heat release rates and rate of decomposition are a function of its temperature. In that regard DTA analysis of a well-defined exothermic decomposition temperature is inadequate in properly assessing the exothermic runaway hazard of any chemical system.

Problems in the past* led to search for new technology.

Much can be learned from past experiences involving thermal runaway reactions that have occurred in the past few years; a partial list is shown below:

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nally from animal and plant tissue. More recently, the trend has been to produce them by submerged fermentation, a generally more economical route.

Typical is the case of rennet used in cheese making. It used to be obtained entirely from calves' stomachs, but this source is becoming increasingly expensive. Also, it does not enable production of sufficient material to satisfy the increasing worldwide demand for cheese. As a result, a microbial rennet, produced by fermentation of a mucor fungus, now is finding acceptance by cheese makers.

Microbial rennet currently accounts for about 20% of all the rennet used. In the U.S., closer to half the rennet requirement is of microbial origin.

Technology also is stepping in to cut costs. An example is development of immobilized enzymes. This involves "fixing" an enzyme to a support medium—a synthetic resin, glass, a fiber, or the like. The desired reaction occurs as a solution of the substrate flows through the columns containing the fixed enzyme.

Glucose isomerase, for example, which is fairly expensive, is used in this way to convert glucose to fructose. "It is doubtful that the economic viability of the process could have been achieved if the enzyme had not been immobilized," Hepner says.

The U.S. market for glucose isomerase is the largest anywhere, and growing. It is used to convert glucose derived from cornstarch to a mixture of glucose and fructose. Called high-fructose corn syrup (HFCS), it comprises about 50% glucose and 42% fructose. Oligosaccharides make up the balance. Its main outlet is in beverages, fruit drinks, and canned fruits. Last year, the amount of HFCS consumed in the U.S. amounted to 4.6 billion lb (on a dry-weight basis). In 1985, the figure is likely to approach 10 billion lb.

Fermentation alcohol for gasohol formulation likely will provide another major boost to enzyme demand. By 1985, some 600 million to 800 million gal of ethanol will be produced for this use in the U.S., compared to less than 100 million gal a year now.

An obvious question that the growing need for bulk enzymes raises is whether existing major producers will have sufficient capacity to keep pace with this demand. Other companies must surely be eyeing the scene with increasing interest.

Dermot O'Sullivan, London

Gasohol: focus shifts to effect on animal feed

Push to produce ethanol for fuel uses could affect what grains are grown, how they will be used, and how much they will cost

Ethanol production involves these costs

Item	Units per gal	Price	Cost per gal
Feedstock	0.385 bushel	$2.50 per bushel	$0.96
By-product credit	6.85 lb	0.065 per lb	(0.45)
Boiler fuel	0.065 million Btu	2.00 per million Btu	0.13
Electricity	1.5 kwh	0.05 per kwh	0.08
Other direct	1.0	0.05 per gal	0.05
Indirect	1.0	0.10 per gal	0.10
Capital cost	1.0	0.33 per gal	0.33
TOTAL	—	—	$1.20

Note: Costs are in 1980 dollars for a 50 million gal per year plant. **Source:** Development Planning & Research Associates Inc

Gasohol—or more specifically the ethanol that goes into it—can't seem to escape from the center of controversy. Originally the arguments were over the energy-balance economics of producing ethanol for fuel. Now that the U.S. has embarked on an ambitious effort to produce ethanol for mixing with gasoline in gasohol blends, the arguments have taken a food-vs.-fuel direction.

The impact of increasing U.S. fuel-grade ethanol production on agriculture was a main focus of a symposium on future food-fuel conflicts held early this month in Toronto at the annual meeting of the American Association for the Advancement of Science. Actually, food-fuel is something of a misnomer for any conflict involving ethanol feedstock, since corn that would be used in producing ethanol is normally used for animal feed.

With U.S. fuel-grade ethanol production currently running in the area of 120 million to 130 million gal per year, the impact on agriculture at present is nil. But that won't necessarily be true in the future, considering current plans to expand production.

In July 1980, Congress set two national production targets for alcohol fuel: a goal of 920 million gal per year capacity by the end of 1982, and that 10% of U.S. gasoline consumption in 1990 be alcohol. These added to an earlier goal announced last January by President Carter that 500 million gal of ethanol be brought on stream by the end of 1981, enabling 10% of all unleaded fuel to be gasohol, the 90% gasoline/10% ethanol mix.

And a further push to accelerate the use of alcohol fuels will be coming soon. Marilyn J. Herman, deputy executive director of the U.S. National Alcohol Fuels Commission, told the symposium that the commission is currently in the process of developing its final report to Congress and the President on steps to accelerate the commercialization of alcohol fuels.

Herman says that after 18 months of analysis, the commission has arrived at three principal conclusions:

- Alcohol-gasoline blends, notably gasohol, can help decrease the consumption of petroleum in the U.S., and use of alcohol as a gasoline extender and an octane booster in blends can offer immediate and continuing oil savings.
- The U.S. must design and make available pure-alcohol vehicles—those capable of running on 100% alcohol—thus providing the impetus to diversify the transportation fuel supply to lessen the disruptive effects of a major cutoff in imported oil.
- The U.S. must proceed to develop available domestic resources to produce both ethanol and methanol, since both fuels will be needed, and each complements the other.

The commission's recommendations, Herman says, address the need to execute existing federal programs fully, revise existing statutes, policies, and programs to remove barriers to alcohol fuels development, and institute new initiatives designed to provide greater energy savings through expanded use of alcohol fuels.

Currently, the focus is on ethanol, particularly that made from corn. And as Milton L. David, president of Development Planning & Research Associates, Manhattan, Kan., notes, the attraction of investors to this industry is readily understood.

A bushel of corn, David points out, will yield about 2.6 gal of ethanol, along with 17.8 lb of distillers dried

Each billion gallons of ethanol requires 2 million acres of new corn production land

Ethanol production, billion gal per year	Corn required, million bushels	Soybeans displaced, million bushels	Soybean acreage reduction, million acres	Corn produced on soybean acres, million bushels	Additional corn required, million bushels	New corn acreage, million acres
1	389	86	2.88	259	130	2.0
2	778	173	5.75	518	261	4.0
3	1167	259	8.63	776	391	6.0
4	1556	345	11.50	1035	521	8.0
5	1946	431	14.38	1294	651	10.0
10	3891	863	28.76	2588	1303	20.0

Note: New corn acreage represents acreage addition required assuming the existing quantity demanded for protein and starch is satisfied in addition to the alcohol demand for starch. **Source:** Wallace E. Tyner, Purdue University

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grains (used in cattle feed) and also carbon dioxide as by-products. A bushel of corn historically has averaged about $2.50 per bushel in 1980 dollars. Thus, the grain cost for a gallon of ethanol is 96 cents. Credit against this of 45 cents per gal of ethanol can be taken for distillers dried grains, which historically have averaged $130 per ton or 6.5 cents per lb. In certain cases, David says, the carbon dioxide may have value, but such cases are the exception.

Processing costs, using available production technology, will be about 70 cents per gal, depending on plant size. Nearly half of these costs are for capital recovery, about a third are for energy, and the remaining 22% are for remaining direct and indirect expenses.

Adding the processing costs to net raw material costs indicates that the total cost of ethanol production, including a fair rate of return, will be about $1.20 per gal. At present, unleaded regular gasoline costs about $1.00 per gal from the refinery. However, there is a 4 cent-per-gal waiver of the federal fuel excise tax on gasoline in gasohol, David points out, which translates to a 40 cent-per-gal subsidy for ethanol if fully captured by the ethanol producer.

The carrots and sticks are thus bound to push ethanol production up dramatically in coming years. And concerns about the impact of this increase on agriculture thus are being voiced.

David points out that assessment of the impact of various levels of ethanol production is complex. Not only are there a number of interrelationships to be considered, he says, but the relationships are not simple one-for-one changes or substitutes. Further compounding analysis of the impacts at high levels of ethanol production is that the values are so great they may fall outside the bounds of historical events upon which relationships used in econometric models are based.

Nonetheless, David says, estimates must be made, and indeed, he has taken a stab at it. From his assessment of what few studies have been made, he believes that a 1 billion gal-per-year ethanol program would have little effect on prices. However, price effects would begin to show up at the 2 billion gal-per-year level. He says he would expect the real price of corn to increase about 7 to 8% and the distillers dried grains price to fall about 20 to 25%. Price effects would be more pronounced at the 4 billion gal-per-year level, he says, with a real price increase in corn on the order of 20 to 25%. The real price of distillers dried grain could stabilize at a price equivalent to corn, he says, since it is at least worth its feed energy value.

At ethanol levels of about 4 billion gal per year, the magnitude of the price effect becomes very problematical. But David guesses that the real price of corn would double at some point between 5 billion and 10 billion gal per year of ethanol. At the 10 billion gal-per-year level, he would expect some rather severe dislocations, particularly with respect to the soybean industry and U.S. feed grain and soybean exports.

A further idea of the complexity involved in analyzing impact on agricultural markets comes from Purdue University agricultural economist Wallace E. Tyner. Use of large amounts of corn for ethanol, he says, would tend to increase corn prices and lead to reduced use of corn for animal feed. Higher corn prices would lead to higher meat prices and, in turn, to reduced consumption of meat products and a shift in the consumption pattern among animal products.

Ultimately, however, the price of corn is related to the price of wheat and other food grains, he says, but the correspondence is not direct. If the price of corn increases, the price of grain sorghum will increase because grain sorghum and corn are close substitutes in consumption. A higher sorghum price will stimulate greater production of sorghum. In the U.S., sorghum and wheat are grown in the same areas, so increased sorghum acreage likely will result in reduced wheat acreage, which in turn will tend to increase the price of wheat. On the demand side, a higher corn price will increase meat prices, which will reduce meat consumption. Reduced meat consumption would tend to increase food grain demand, which would cause the wheat price to increase.

Another aspect of corn production for ethanol is its relationship to soybeans. The distillers dried grains produced as a by-product of ethanol production contain about 27% protein and 12% fiber and are useful as protein supplements for beef and dairy cattle. In this role, they substitute for soybean meal and other high-protein animal feeds, with about 1.63 lb of distillers grain containing the protein in 1 lb of soybean meal. Potentially, Tyner says, distillers dried grain could replace much of the soybean meal used in cattle diets and to the extent this occurred, soybean acreage

would decrease and corn acreage increase.

The result of computations concerning such substitution, Tyner says, shows that each billion gallons of ethanol produced from corn would require 2 million acres of new land in corn production. In the U.S. in 1980, about 80 million acres were planted to corn and 70 million acres to soybeans. In 1978, there were about 13 million acres in corn and wheat land diversion programs, of which 4.6 million acres was corn land. Thus 2 billion gal of ethanol could be produced with a net addition of 4 million acres of corn land, which is less than the 1978 set-aside.

Taken with other analyses, Tyner says, these results all tend to indicate that at relatively low levels of alcohol production—1 billion to 2 billion gal per year—corn price increases and required land supply increases would be relatively small. However, at higher levels of ethanol production, the impacts would be more serious.

All of this is assuming that corn would be the only feedstock for fuel-grade ethanol. But as Herman points out, present production of ethanol shows the diversity of raw materials that can be used. Current production in the U.S. is coming from such materials as grain, cheese whey, sulfite pulping waste, culled potatoes, and citrus molasses.

The future potential for alcohol fuel, Herman says, rests in the supply of diverse biomass feedstocks. And the development of technology to utilize cellulosic waste material from biomass will be a key factor in the ability to produce larger amounts of alcohol. Within four to five years, she says, the commission expects to see commercial processes developed that will be able to convert cellulose plant fiber into alcohol, thus opening up such new sources of feedstock as corncobs, trees, sawmill wastes, crop residues, and even garbage.

Any long-term competition between fuel and animal feed uses of grains resulting in high food price increases, Herman says, can be avoided if concerted efforts are made now to expand research on technology for production of ethanol and methanol from cellulosic materials and on plant genetics to develop new sugar, starch, and cellulose energy crops. Also, ways must be found, she says, to review, through normal policy-making processes, national needs and priorities for energy, feed, and exports of agricultural products in light of the overall necessity to reduce oil imports. □

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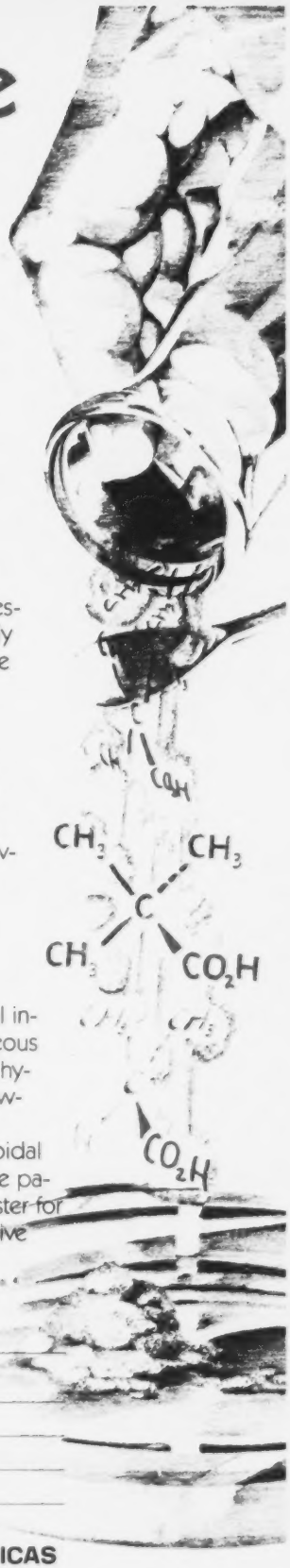

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Natural gas-based petrochemicals—
1981 will be surprisingly good
A Key Chemicals Review Page 15

Chemical & Engineering NEWS

January 26, 1981

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FEDERAL R&D BUDGET

Pentagon's share rises to 48% Page 23

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January 26, 1981
Volume 59, Number 4
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ISSN 0009-2347

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- ***Brookings Institution fellowship program*** *will bring senior scientists to Washington, D.C., for research in which they can apply their knowledge to public issues.* ***Page 10***
- ***Rigid labeling regulations*** *to protect workers from hazardous chemicals proposed by OSHA.* ***Page 11***
- ***Earnings reports*** *issued by four U.S. chemical companies are mixed; however, fourth-quarter profit margins may be lower, as sales outrun earnings.* ***Page 11***
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- ***Advisory board members*** *have been named for most ACS publications.* ***Page 45***

Gas-based petrochemicals set for good year

Fertilizer and gasoline demand will fuel growth for ammonia, urea, and methanol, but weak housing market will hurt formaldehyde use

Producers of the leading small-molecule chemicals made from natural gas (methane)—ammonia, urea, methanol, and formaldehyde—are looking forward to a generally good year in 1981. Producers' optimism comes from good health in two basic consumer markets—food and fuel—which generally will outweigh the dampening effect from another consumer market in housing.

Production of all four chemicals in 1981 likely will increase over that in 1980. One, formaldehyde, probably will not make it back to 1979 production levels after its drop in the 1980 recession. The others likely will exceed 1979 production this year, ammonia and urea most assuredly because their production did not drop at all in 1980.

The average 1981 production increase for the group will not be all that great, about 3.1% to a total of 73.2 billion lb. The reason for the small increase is largely plant capacity limitations in the two largest-volume products, ammonia and urea. And methanol, too, could test capacity limits.

Because of the large differences in production volumes, with good-performing ammonia at one extreme nearly nine times larger than weak-performing formaldehyde, the group managed an overall 1% production gain in 1980 despite the recession, which generally hurt production in the chemical industry. Production increased for both ammonia and urea in 1980, offsetting declines in methanol and formaldehyde.

Because relatively little new ammonia capacity is being built in the U.S., gains in production probably will be small for ammonia and derivative urea for the next few years. However, total U.S. consumption of ammonia either directly or in derivatives will continue to grow, buoyed by increased imports of ammonia and derivatives from Canada and Mexico.

In 1981, the estimated commercial value of these four chemicals produced in the U.S. will be a total of $5.25 billion, up 22% from 1980. This rise represents both increased volume and higher cost of natural gas, used as both raw material and energy.

The fractional increase in value of production in 1981 will be larger for methanol and formaldehyde than for ammonia and urea. This is due to the relatively greater increase in output from available capacity.

Closer analysis of production values suggests that profits are not rising in direct relationship to sales. In effect, producers in 1981 are expected to get profits back to the rather poor levels of 1979. Producers will be mostly passing on the ever-increasing costs of natural gas as expensive new gas contracts replace the old, some of which set very low prices.

Increasing gas costs in recent years have spurred producers to look at a number of cost-cutting moves. One important example that produced results in 1980 is methanol production by Du Pont outside Houston using a residual fraction from crude oil in place of natural gas for feedstock. Another example is plans for a demonstration unit making ammonia from coal.

These changes, although significant, are merely in the basic feedstock, not in the actual manufacturing technology. The commercial reactions making ammonia and methanol, essentially from synthesis gas (carbon monoxide and hydrogen) remain the same. Instead of obtaining the hydrogen mainly from natural gas, the new methanol and ammonia plants will get it largely from water reacted with the carbon of the heavy oil fraction or of coal.

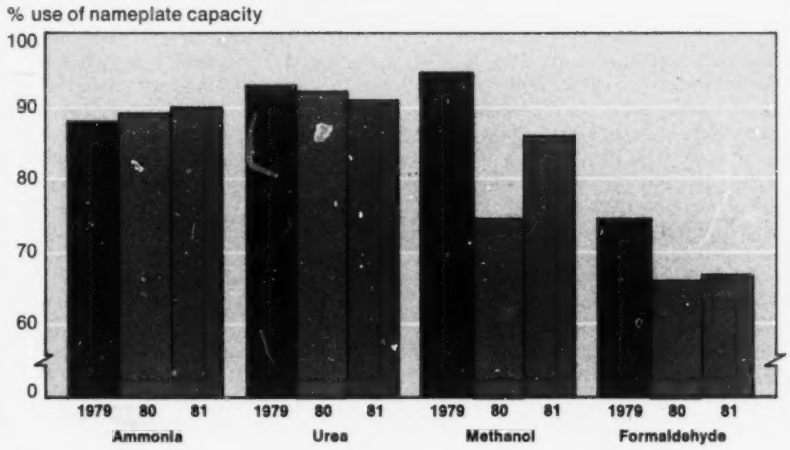
This production change may not make the overall process any less expensive in today's dollars. However, producers hope to keep the rate of cost increase below what it might have been if gas continued to be the feedstock.

These changes in feedstock from natural gas to residual oil fractions and coal either now commercial or coming in the next few years likely also will bring a name change to this group of key chemicals. Because the products from the reaction of steam and carbon are mainly carbon monoxide and hydrogen—synthesis gas—these products more commonly will be known as "syn gas chemicals."

For the immediate market outlook for the four gas-based chemicals, see the following pages.

Bruce Greek, Houston

Plant capacity use will be quite high this year for ammonia, urea, methanol



Sources: Industry, C&EN estimates

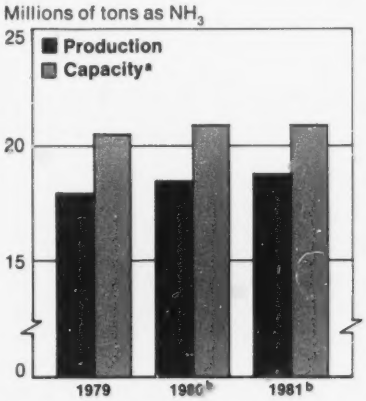
Key Chemicals

NH_3

Ammonia

- ***Demand good***
- ***Capacity flat***
- ***Prices firming***

PRODUCTION/CAPACITY



a First quarter. b Excludes up to 15% additional capacity generally shut down.

HOW MADE

Catalytic reaction of nitrogen from air and hydrogen from natural gas

MAJOR DERIVATIVES

Nitric acid 20%, urea 20%, ammonium phosphates 15%

MAJOR END USES

Fertilizer 80%, plastics and fibers 10%, explosives 5%

FOREIGN TRADE

Exports—climbing to about 750,000 tons in 1981, imports—rising to more than 2 million tons this year

PRICES

$135 to $145 per ton at Gulf Coast plants

COMMERCIAL VALUE

$2.5 billion for total production, 1981

After a rough time in the mid-1970's, the past two years have looked considerably improved for U.S. ammonia producers despite the recession and increasing imports. This year looks even better.

This winter, producers probably will be able to sell all the ammonia they can get out of their plants. U.S. production will be augmented by a small net inflow of ammonia and derivatives from abroad. The driving force will be continued good health in the dominant market, nitrogen fertilizers.

Even though operating plant capacity is holding steady at 20.7 million tons (as NH_3), production in 1981 is expected to rise a bit to about 18.7 million tons from about 18.5 million tons estimated for 1980. To achieve this gain, producers are expected to run their plants at 90% of nameplate capacity on average. At times such as the peak fertilizer season this spring, plants will be pressed hard. Operations frequently will exceed 100% of nameplate capacity, going as high as 110%, according to industry sources.

More specific reasons for this expected high level of plant operation are the same as last year. In areas such as Texas where the winter weather has been favorable, farmers' optimism has grown, and with it their purchases of fertilizer. Exports of fertilizers such as urea and diammonium phosphate are expected to be about as strong as they were last year. In addition, U.S. farm commodity prices are expected to hold up or improve generally, providing money for buying fertilizer even though farm debt is high.

On an annual basis, U.S. and imported ammonia is expected to just about meet all market needs this year. Since fertilizer demand is very seasonal, temporary logistic problems could cause shortages at the main application time this spring.

Unfortunately, high interest rates are causing farmers and dealers to hold down fertilizer inventories again just as the planting season approaches. If a scramble follows to meet demand with good weather conditions in the corn belt, inventories are expected to be very low by early summer.

This seasonal demand in fertilizer will interact with alternative demand for exports and industrial (nonagricultural) uses for ammonia derivatives this year. At the height of spring planting, exports may drop despite demand if U.S. farm uses get priority.

Industrial uses such as in fibers and plastics could be down for the year anyway because of lower demand in housing and automobiles. This decline actually could be a plus, allowing ammonia producers to satisfy the tight fertilizer market more easily.

The spring push in nitrogen fertilizer is beginning now along the Gulf Coast. Prices have risen $10 to $15 per ton in less than a month to nearly $150. Ammonia prices tend to run on the low side in Louisiana and toward the high end of the price range in Texas. Prices for ammonia are forecast to continue to rise during the 1981 planting season and to remain above last year's levels. Higher prices for natural gas will be the sustaining factor after the flurry of increases during the brief shortage.

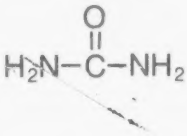
Prices on the Gulf Coast can be strongly influenced by imports, although U.S. market forces prevail at present. Depending on the season, import volume affects spot market prices radically and contract prices to a lesser extent. For example, large-volume imports from the Soviet Union are currently following U.S. contract prices. However, this can't necessarily be depended upon for the future.

A few years from now, imports of ammonia from the Soviet Union may be replaced at least in part by added imports from Canada. Plant expansions announced in Canada total about 50% of existing Canadian capacity of about 2.8 million tons. If these expansions are finished on schedule through 1985, the added supply will exceed growth in that country's demand. Of course, not all of the added production will be exported, and not all will be sold as ammonia, since demand for derivative formulations such as urea-ammonia nitrate solutions is growing well.

To the south, some small expansion plans are stirring in the U.S. now, although nothing like the size of capacity additions coming in Canada. Two back-to-back years of operation at practical top capacity appear to have coaxed out a little investment money, particularly in derivatives. By the mid-1980's, the new capacity will become at least a small additional reality.

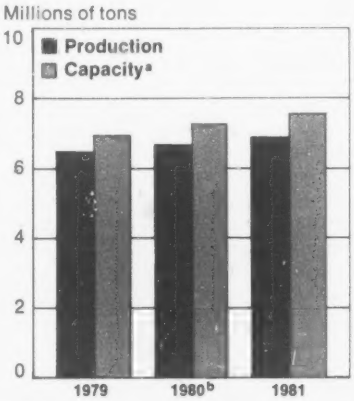
Key Chemicals

Urea



- ***Demand strong***
- ***Capacity up a bit***
- ***Prices rising***

PRODUCTION/CAPACITY



a First quarter. b Excludes 5 to 10% additional capacity generally shut down.

HOW MADE

Reaction of ammonia and carbon dioxide under pressure

MAJOR DERIVATIVES

Urea-formaldehyde resins 10%, melamine resins 5%

MAJOR END USES

Fertilizer 75%, adhesives and plastics 15%, animal feed 5%

FOREIGN TRADE

Exports—up to about 2 million tons in 1981, imports—rising to about 1.7 million tons in 1981

PRICES

$160 to $190 per ton, depending on location and grade

COMMERCIAL VALUE

$1.25 billion for total production, 1981

As forecast by the industry last year, U.S. urea production ran full out in 1980. It probably will stay the same in 1981 and 1982 for this favored fertilizer material.

In 1981, urea production likely will be near 7 million tons, up about 5% from last year. Because of discrepancies in official reporting such as double counting or neglecting of urea not isolated, government data are considered less accurate than for most other chemicals.

Estimates of urea's nameplate plant capacity also are more difficult to make than for most other chemicals because of the large number of plants with widely varying capacities. Undisclosed plant modifications, transfer of production units to new sites, and technology changes further complicate estimates for plant capacity.

If urea production reaches 6.9 million tons in 1981, estimated capacity of 7.6 million tons will be operated at an average rate of more than 90%. This rate is considered above the nominal top rate for plants handling a moderately corrosive feedstock stream.

Some industry observers believe that the rate will not get this high because plants will have to be shut down for extended maintenance this year. The reason is that urea plants have been operated at high rates for the past two years under pressure of both domestic and export demand.

Currently, a small amount of extra plant capacity might yet be available if high prices justify its use. How much extra will depend on factors such as sufficient feedstocks (ammonia and/or carbon dioxide) and product transportation costs. Estimates for this capacity cluster around 300,000 tons of annual nameplate capacity and range up to about 500,000 tons.

If extra capacity is indeed available and usable, this urea apparently could be sold without difficulty. However, plant location has a limiting effect on one important urea market—exports. Lack of capacity near ports seems to be limiting exports and probably will continue to do so for much of 1981. If U.S. demand slumps because of bad weather, some existing urea production could be diverted to exports.

Despite some limitations, urea has unusually large exports and imports relative to total production. In general, plants located on the Gulf Coast and the lower Mississippi River handle most of the export urea business for reasons of transportation costs.

Imports generally move overland from Canada to areas relatively far from most U.S. urea production. Much of Canadian capacity for the chemical is located some distance from seaports, thereby reducing the potential for ocean shipment abroad.

Although the industrial (nonfertilizer) uses of urea, mainly as a raw material for resins and plastics, show considerable growth, agricultural uses still dominate. About 75% of urea goes to produce fertilizers and 5% to animal feed. Fertilizer use continues to grow strongly, particularly in the U.S. market for urea-ammonium nitrate (UAN) solutions.

Solution fertilizers, now more than ever dominated by UAN, are growing because of low cost in blending and in applying to fields. As a result, investment is on the rise for storage facilities allowing further increases in solution use.

The other side of the agricultural market, animal feed, appears to have wide swings in urea use, up to 25% per year. Cost competition from other sources of nitrogen in animal feeds accounts for these swings. However, the base is small, and the net effect on urea demand is not significant.

Industrial uses for the urea-formaldehyde resins probably will be down a bit in 1981 because of lower demand for particleboard used in homes and light commercial construction. Other uses of these resins in paper, textile sizes, and surface coatings will not change enough to affect urea demand. If anything, eased industrial demand could help agricultural supply at a time when more urea is needed.

As might be expected, consecutive good years for urea are beginning to bring out plans for new capacity. One 330,000 ton-per-year plant is under construction by Farmland Industries at Enid, Okla., scheduled to start up in January 1982. More new capacity is rumored. A side result is that urea might be a big spur to new raw-material ammonia capacity.

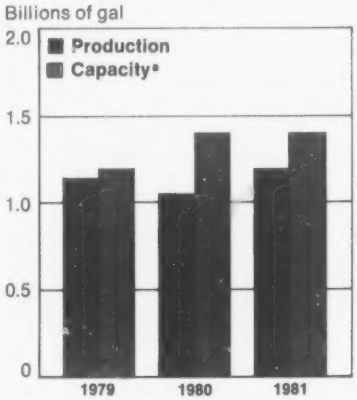
Key Chemicals

CH_3OH

Methanol

- ***Demand back up***
- ***Capacity up slightly***
- ***Prices steady***

PRODUCTION/CAPACITY



[a] First quarter.

HOW MADE

Reaction of carbon monoxide and hydrogen made by reforming natural gas or heavier hydrocarbon fractions

MAJOR DERIVATIVES

Formaldehyde 45%, acetic acid 10%, methyl tert-butyl ether 5%

MAJOR END USES

Polymers used as adhesives, fibers, and engineering plastics 60%

FOREIGN TRADE

Exports—moving up to 60 million to 70 million gal this year, imports—holding at about 40 million gal in 1981

PRICES

Contract 75 cents per gal at plant

COMMERCIAL VALUE

$1 billion for total production, 1981

Recovering from the 1980 recession, U.S. methanol production in 1981 probably will exceed production in 1979, but not by very much. In other words, methanol will have had two years of essentially no growth, like many other basic organic chemicals. If methanol is to match 1979 production this year it will take strongly improved demand in the second half.

Methanol production this year probably will be 1.15 billion to 1.20 billion gal, up about 10% from 1980 production. This 1981 estimate barely exceeds 1979 production of 1.14 billion gal of the alcohol.

Plants' nameplate capacity for methanol hasn't changed very much from a year ago, remaining about 1.14 billion gal per year. A shift to lower-pressure technology is adding a slight amount now after a 200 million gal jump in late 1979 when Du Pont's new methanol plant outside Houston came on stream.

If production in 1981 reaches 1.2 billion gal of methanol, plants will run on average a bit more than 85% of first-quarter capacity. However, because of additional capacity expected on stream during the year, the typical plant will run below 85%. Such a rate won't completely please companies' financial people, but operating personnel will feel a little easier than they have in the past two years. Before the lean recession days in 1980, swollen demand for methanol put pressure on to keep plants running beyond the time that operators should have shut them down for maintenance.

Demand for, and therefore production of, methanol relates to the chemical and general economy in a complex but distinctly cyclical pattern. This economic cycle can swing methanol production 10% per year with ease. Although not so bad as the effect on many other organics, these fluctuations can be sudden.

The low level of housing starts since mid-1980 has hurt methanol production through a slowed demand for methanol's dominant derivative, formaldehyde. Other uses of methanol, except methyl *tert*-butyl ether (MTBE), dropped too, pulling down total production in 1980.

The big housing market, which takes methanol in adhesives for particleboard and plywood as well as in many other smaller uses, likely will remain below the 1979 level during 1981. If interest rates ease and another rate increase doesn't again torpedo the recovery in housing starts as it did this past fall, housing is expected to improve in the second half of 1981. However, the biggest impact on methanol of an upturn in housing in 1981 will wait until 1982, when demand will translate back through the pipeline to resin makers and organics suppliers.

The many other small uses of methanol, none of which exceed 10% of production, face little or no gain in 1981 because of the economy. Use in chemicals such as dimethyl terephthalate (DMT) and methyl methacrylate is influenced by synthetic fiber and plastics demand. Methanol producers think that polyester fibers from DMT will do well this year to match even 1980 levels, although fiber producers are more hopeful (C&EN, Dec. 1, 1980, page 9).

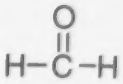
Even the fast-growing use of methanol in MTBE has met problems. Production of MTBE in 1980 still didn't meet expectations of many methanol producers. The problem was not in end demand or methanol supply but in supply of raw material isobutylene.

Isobutylene's pinch traces in part to a weakened market for major olefin products such as polyethylene, polypropylene, and polyvinyl chloride. At the same time, choice of feedstock for olefins-producing steam crackers moved toward lighter hydrocarbons. Both influences reduced crackers' output of C_4 olefins, including isobutylene.

In 1981, MTBE production and use are expected to continue to grow smartly and take more methanol, especially if ways are found to increase production of isobutylene from sources other than steam crackers, such as oil refineries. Blends of methanol and other alcohols such as *tert*-butyl alcohol are expected to continue to grow for use as octane boosters in gasoline, further adding to the push in fuel use for methanol. These uses, plus a possible small gain in exports, underlie producers' hopes for offsetting a decline in methanol use in formaldehyde to bring 1981 methanol production above that of 1979.

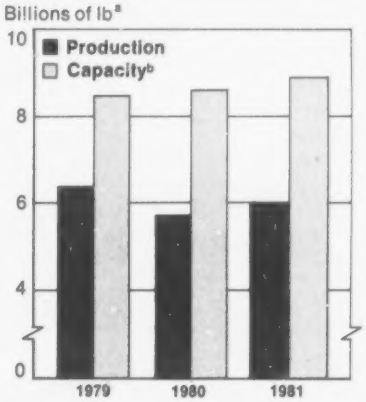
Key Chemicals

Formaldehyde



- ***Demand soft***
- ***Capacity to rise***
- ***Prices holding***

PRODUCTION/CAPACITY



a As a 37% solution. b First quarter.

HOW MADE

Catalytic oxidation of methanol

MAJOR DERIVATIVES

Urea-formaldehyde resins 30%, phenol-formaldehyde resins 25%, polyacetal resins 5%, butanediol 5%, pentaerythritol 5%

MAJOR END USES

Adhesives 60%, plastics 15%

FOREIGN TRADE

Exports and imports negligible

PRICES

7 to 8 cents per lb as 37% solution, depending on location, additives, and the like

COMMERCIAL VALUE

$550 million for total production, 1981

As in 1980, toxicity will be the big news for formaldehyde, with a possible ban on use in home insulation (C&EN, Jan. 19, page 11). Such a move, however, will have little impact on overall formaldehyde production and sales. The state of the U.S. economy will be much more important in determining formaldehyde's fortunes this year.

Even without the toxicity issue, this methanol derivative will have another so-so year in 1981. Formaldehyde production is expected to rise slightly, about 5%, to 6 billion lb from the depressed level of 5.7 billion lb (as 37% solution in water). This 1981 estimate still would be 6% below the 1979 formaldehyde production level.

Perhaps more unfortunately, formaldehyde's nameplate plant capacity in 1980 rose only a bit less than the expected production gain in 1981. Still more capacity is due on stream this year. Additions are expected to total about 500 million lb in 1981 adding to first-quarter capacity of 8.9 billion lb. A year ago, capacity was 8.6 billion lb. Somewhat offsetting the 1981 additions will be shutdowns of old, small units totaling about 100 million lb of 37% solution material, leaving capacity at 9.3 billion lb at year's end.

Because most of the new capacity is due on stream in late 1981, existing plants will run about 70% of nameplate capacity over the year if production reaches 6 billion lb. Industry sources, however, forecast lower rates for the first half because of the depressed housing market for wood products, which use large quantities of formaldehyde in adhesives. If interest rates decline enough to spur housing, the second-half production rate will exceed the estimated annual average, even with the capacity additions.

Formaldehyde's overcapacity, compared to the capacity of the other major products made from synthesis gas (carbon monoxide and hydrogen), clearly shows its maturity as a product. Excluding the peculiar ups and downs in formaldehyde growth owing to housing swings, the trend line is settling down near the growth rate for constant-dollar gross national product.

Much of this maturity stems from a lack of new derivatives with high potential growth. At one time, polymers made from formaldehyde, the polyacetals, were thought to be the product that would put formaldehyde's growth back to levels of the 1960's and 1970's. However, polyacetals, as engineering plastics, found markets largely in highly cyclical consumer durables such as autos, which are currently in a slump equal to that of housing.

The latest blow to formaldehyde's market growth is its toxicity problem. The proposed ban on use of urea/formaldehyde insulation as well as possible upcoming regulations on formaldehyde emissions in the workplace would only further crimp long-term growth. Although these particular problems may be solved without much inherent effect on demand, the attendant publicity will work against the entire formaldehyde market, including development of new uses for this reactive compound.

Besides its uses in adhesives for plywood and particleboard, which take about half of total production, formaldehyde goes into a wide variety of polymers and intermediates. Unfortunately, many of these derivatives also are maturing. The polyacetals, for example, are looking more and more mature. That is, their growth has fluctuated widely since the mid-1970's pretty much in line with the demand for durable goods such as automobiles and appliances.

A host of smaller uses of formaldehyde are growing reasonably well, but they don't count much in total formaldehyde use. For example, demand for trimethylolpropane (or, correctly, 2-ethyl-2-(hydroxymethyl)-1, 3-propanediol), used in making polyether polyols for polyurethane coatings and foams, is growing at perhaps 5% annually. However, its long-term outlook depends on growth in polyurethane, which has some potential problems of its own from combustion products.

These pluses and minuses give a current formaldehyde outlook of slow net growth. Producers will be taking a close look at the economics of their plant operations, which could favor buying formaldehyde resins on the open market, rather than producing them captively. So after this year, it may be a while before much new investment goes into formaldehyde plants.

Big gains for R&D in Carter's final budget

With total R&D funds slated to rise 18%, the question is not if, but how much of, this will be cut in Reagan's revised budget

Janice R. Long, Lois R. Ember, and David J. Hanson
C&EN, Washington

Office of Management & Budget director David Stockman already is talking about the necessity of revising President Carter's fiscal 1982 budget from top to bottom as part of the effort to clamp down on federal spending. No mean feat in a budget that runs into hundreds of billions of dollars and spreads over 2000 pages in three big volumes.

Nevertheless, the Reagan Administration could have its budget proposals before Congress in late February or early March. Just how deeply R&D funding will be affected by the budget cuts won't be known until then. Right now opinion in Washington is about evenly divided between fears that research money, particularly basic research money, will offer a tempting target for easy cuts, and belief that with the new Administration's emphasis on increasing productivity and innovation, R&D will be fairly safe.

One thing is certain. The final fiscal 1982 federal budget will be quite different from the one Carter proposed once the Reagan Administration, and, more important, Congress have worked their will on it. But then no final budget ever does look like the proposed one.

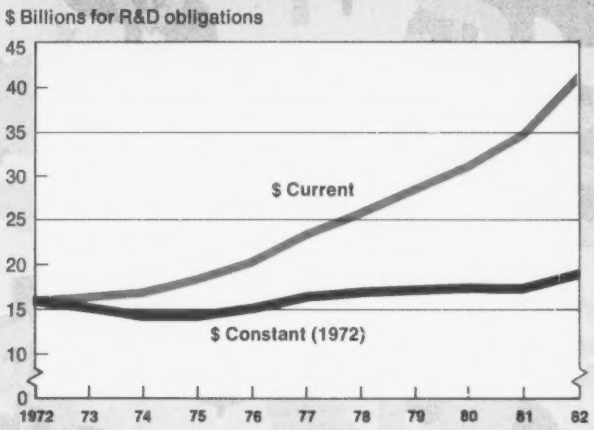
The document all these people will be taking apart calls for federal outlays to rise 11.5% to $739.3 billion. Receipts would be up 17%—no tax cuts here—to $711.8 billion, leaving a $27.5 billion deficit. When the fiscal 1981 budget was proposed last January, the deficit was estimated at $15.8 billion. The latest estimate is that it will hit at least $55.2 billion.

Under the Carter budget proposal, total federal R&D obligations would be up 18.5%, or $6.5 billion, to $41.7 billion. Outlays would be up 16.6%, or $5.6 billion, to $39.6 billion. Inasmuch as the Carter economic advisers predicted a 1982 inflation rate of 9.3%, the increase could allow for some real growth in R&D funding. The largest increases are slated for the Department of Defense, 23.4%, and the National Aeronautics & Space Administration, 21.5%.

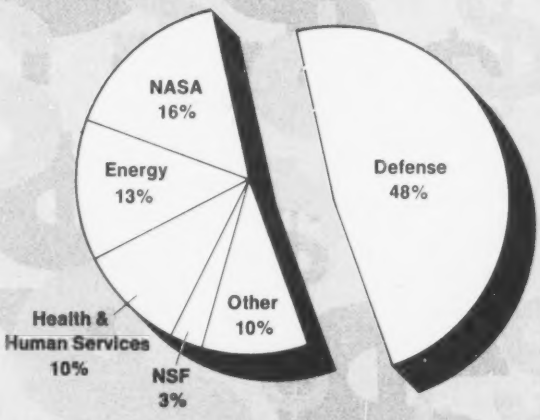
As it has for the past several years, basic research also would do quite well. Obligations would be up 14% to $5.9 billion. Outlays also would be up 14% to $5.5 billion. According to figures from the Office of Science & Technology Policy, basic research obligations increased 58.2% between fiscal year 1978 and fiscal 1982, allowing for 11% real growth.

Federal support for R&D at colleges and universities is also up. Obligations under the proposed budget would

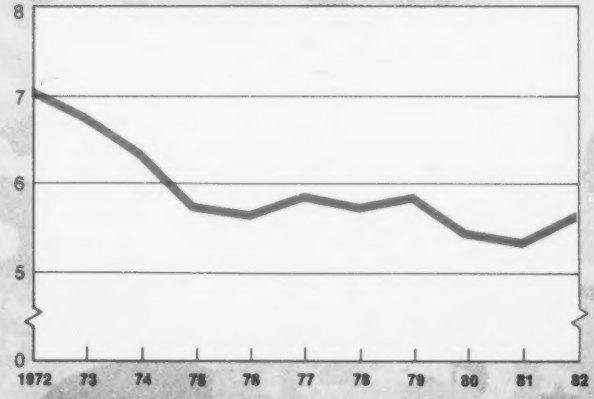
R&D funds slated to be up 9% in constant dollars



Department of Defense gets largest share of R&D budget



R&D funding increases slightly to 5.7% of federal budget



be up 11%, following an 8% rise in 1981, to $5.1 billion. Doing best of all under the proposed budget are R&D facilities, obligations for which would be up 27%, or $516 million, to $2.4 billion. Outlays also would be up 23%, or $436 million, to $2.4 billion.

A breakdown of the federal R&D budget by agency shows DOD with an even slightly larger slice of the pie, 48%, than the 46% that it previously had. In fact DOD's $196.4 billion proposed budget for fiscal 1982 will be about 26% of the entire U.S. budget, but most of the money is going for operation and maintenance and for the purchase of new weapons. Proposed spending for research, development, testing, and evaluation at DOD for 1982 is $20 billion, a $3.8 billion or 23% increase over obligations for these activities from 1981. Still, even with this large increase, the R&D funds are just 10.2% of the DOD budget plan, down slightly from 10.4% for 1981.

Most of DOD's R&D funding goes for development and testing of strategic and tactical military systems, but the basic research programs are set to receive a $99 million increase, or about 16%, to $704 million. This percentage is higher than last year, when basic research increased 12%. In addition to research, a $44 million hike in spending for R&D facilities is requested, an almost 10% increase from 1981 levels.

Of the R&D funding going for weapons development, the two largest programs are the MX missile, funding for which is scheduled to be increased $900 million to $2.4 billion, and the cruise missile project, funding for which would rise to a total of $1.5 billion. Major tactical programs funded are an antisubmarine helicopter, a larger gun for the XM-1 tank, and a new long-range artillery rocket system.

Considerable budget growth after allowing for inflation is planned for work on increasing DOD's technology base, most of which is basic research. It is too early to have details on how funding is to be apportioned, but funds will be channeled into electronics, materials research, environmental research, computer science, behavioral research, and work on lasers and particle beams. A spokesman at DOD sees new programs in chemical defenses—particularly protection against chemical warfare—and in the area of surface science for development of ultrasmall electronics.

The defense activities of the Department of Energy also are slated for a very sizable increase in fiscal 1982, as is DOE's overall budget. Funding for defense activities, which accounts for 29% of the department's total budget, would be up 28%, or $1 billion, to $4.7 billion. Weapons activities are slated for a 31% increase to $3 billion, with $1.3 billion, an increase of 12%, earmarked for R&D and testing. Funding for materials production would be up 26% to $837 million; defense waste management up 17% to $350 million; naval reactor development up 14% to $346 million; verification and control technology up 26% to $50 million; nuclear materials security and safeguards up 2% to $48 million; and security investigations up 50% to $24 million.

DOE's total budget would be up about $2.9 billion, or 21%, to $16.5 billion. Energy activities would get 41%, or $6.8 billion of the total; the strategic petroleum reserve, 24% or $3.9 billion; general science, 4% or $607 million; and administration the remaining 2% or $402 million.

DOE's civilian R&D programs, though not faring so well as its defense programs, would not do too badly either. The agency's funding authorities (which are equivalent to other agencies' obligations) for civilian R&D programs would increase $621 million, or 14%, to $4.9 billion. Outlays would be up $784 million to $5.0 billion. DOE says that it will be making a significant move away from near-term R&D activities in fiscal 1982 while increasing its emphasis on long-term basic research.

This redirection is obvious in the proposed budget which, although it is up overall, does contain decreases for a number of programs. Geothermal R&D would be down 41% to $91.6 million; research on energy storage systems down 17% to $59.5 million; solar R&D down 10% to $440 million; and nuclear R&D down 6% to about $792 million.

Slated for a whopping increase, 41%, is the fossil energy budget, which would be set at $1.5 billion. All of the increase is due to a 49% increase, to $1.4 billion, in the coal R&D budget, which DOE says is needed to cover construction of major demonstration facilities. The other fossil R&D programs are facing budget decreases. Authorities for petroleum and natural gas R&D would be down 5% to $81.6 million and those for magnetohydrodynamics down 10% to $60 million.

Other program increases are slated for general science and research, up 19% to nearly $606 million; fusion, up 28% to a little more than $506 million; environmental R&D, up 18% to $280 million; and conservation R&D, up 10% to more than $304 million. Authorities for basic energy sciences would be up 26% to $308 million, with funding for chemical sciences up 24% to $84 million and that for materials sciences also up 24% to about $118 million.

The National Aeronautics & Space Administration continues to have the largest civilian commitment to R&D with a requested $6.7 billion budget for fiscal 1982. This represents a 22% increase over 1981 funding. The agency has earmarked more than $1.1 billion of the total for research and program management.

Much of the funding would go into completion and space flight operation of the space shuttle, now scheduled to make its first orbital trip in March. Other long-running projects also would get some significant increases,

Glossary of budget terms

Authority. Permission to incur obligations, requiring either immediate or future payment, which will become available during the year. Appropriations on which Congress acts are the most common form of budget authority, allowing federal agencies to make payments out of the Treasury for specified purposes.

Deferral. Any executive branch action or inaction that delays the availability of budget authority for obligations. Deferrals may not extend beyond the end of the fiscal year and may be overturned at any time by either branch of Congress.

Fiscal year. Year running from Oct. 1 to Sept. 30. The fiscal year is designated by the calendar year in which it ends.

Obligations. Commitments made by federal agencies to pay out money for products, services, or other purposes, as distinct from the actual payments.

Outlays. Payments for obligations incurred under budget authority, generally made by issuance of checks by Treasury. Outlays during any fiscal year may be payments of obligations incurred in prior fiscal years or in the same fiscal year.

Recission. Enacted legislation canceling budget authority previously granted by Congress. Recissions proposed by the President must be approved by Congress within 45 days to become effective.

however, as they reach critical stages. The large space telescope, expected to be launched from the shuttle in 1985, is an exception; it is on hold, with requested funds the same as last year at $119 million. The earth radiation experiment budget, though, would be up 18% to $24 million. The upper atmosphere research program is slated to jump 11% to $15 million. The gamma ray observatory work is proposed to nearly triple its funds to $52 million. And the international solar polar mission is expecting a 46% increase to $58 million.

The higher funding request would leave room for some new initiatives at NASA. Some of these are a Venus orbiting imaging spacecraft to be launched from the shuttle in 1986 to help map Venus, funded at $40 million and a geological applications program that eventually could contribute to the discovery of new sources of natural gas and oil, funded at $10 million.

The 1982 R&D budget for the Department of Health & Human Services as proposed by the Carter Administration would climb to $4.3 billion, an increase of $321 million over the 1981 level. Within this total, basic research funding is pegged at $2.1 billion, up 9%.

The National Institutes of Health would receive the largest share of the department's R&D funds, fully 80% or $3.6 billion. The increase of $193 million in NIH's obligations is aimed at ensuring continuity in biomedical and behavioral research. In fact, an increase of $154 million to $1.9 billion is earmarked to provide about 5000 new, competitive awards to individual scientists or research teams.

The National Toxicology Program, established in 1978 and headed by David Rall, director of the National Institute of Environmental Health Sciences (NIEHS), is budgeted at $64 million for fiscal 1982, with an additional $6 million to come equally from the National Cancer Institute and NIEHS budgets. One objective of the toxicology program is to provide toxicological information needed by other federal research and regulatory agencies.

In addition to the toxicology program, NIH's basic and applied research will continue to focus on nutrition, genetics, diabetes, aging, and radiation and other environmental insults. Among the major efforts to be supported are:

- Studies on the cause and prevention of diseases associated with such environmental agents as chemicals and radiation.
- Efforts to develop procedures and methodologies for the conduct of recombinant DNA research.
- Studies to elucidate the role of nutritrion in cancer, cardiovascular disease, childhood development, and aging.

In a budget proposal in which research did quite well, NSF fared very well indeed. Its overall budget would rise almost 24% to just over $1.3 billion. Obligations for research and related activities also would be up 23% to $1.2 billion, and those for science and engineering education would be up 39% to almost $112 million.

The major new initiative in NSF's fiscal 1982 budget is a $75 million university research equipment and laboratories program. NSF says it would make up to 120 awards, one per institution, under this program in any field of science or engineering. Awards would be based on each institution's self-determined highest priority need as expressed in its proposal to NSF.

But a number of old initiatives also would continue to receive strong support. Funding for university/industry cooperative research projects would rise more than 90% to $26.8 million, and that for the small business innovation program would just about double to $14.5 million.

More important, funding for basic research would increase 14.4% to $1.1 billion and that for applied research would rise 10.6% to $90.0 million. Applied research now will be funded by all of NSF's directorates instead of by the old engineering and applied science directorate, which has been reorganized and renamed the directorate of engineering.

Basic research funding up 14% to almost $5.9 billion

$ Millions	1982[a]	1981[a]	% change 1982–81
HHS	$2053	$1887	8.8%
NSF	1057	923	14.5
Energy	710	591	20.0
Defense	704	605	16.4
NASA	681	555	22.7
Agriculture	367	322	14.0
Interior	99	85	16.5
Smithsonian	53	44	20.4
Commerce	41	33	24.2
Education	24	18	33.3
EPA	13	15	−13.3
Others	60	44	36.4
TOTAL	$5862	$5122	14.4%

a Estimates. **Note:** Obligations.

R&D funding at DOD set to jump more than 23%

$ Millions	1982[a]	1981[a]	1980[b]
Tactical programs	$ 6,955	$ 5,630	$ 5,296
Strategic programs	4,093	3,248	2,250
Technology base	2,998	2,534	2,235
Program management and support	2,618	2,081	1,914
Intelligence and communication	1,958	1,522	1,162
Advanced technology development	796	613	618
Other	615	598	468
TOTAL	$20,033	$16,226	$13,943

a Estimate. b Actual. **Note:** Obligations.

Funding for the mathematical and physical sciences directorate would be up 17% to about $301 million. Within the directorate, support for scientific research projects would increase 16.8%, to more than $209 million. NSF says it plans to achieve significant real growth in its mathematics, chemistry, and materials research awards by holding the number of investigators funded to fiscal 1981 levels. By doing so, NSF says it will be possible to provide more adequately for instrumentation, materials and supplies, technical support, and other research-related requirements.

Funding for materials research would rise 15.7% to $88.5 million, and funding for chemical research would increase 16.3% to $67.2 million. The $9.4 million increase would be spread fairly evenly among all the chemistry program areas, with funding in all but one increasing 16 to 18%. The one exception is chemical instrumentation, whose funding on paper would be up only 7%. However, NSF is ending its support of the National Resource for Computation in Chemistry in fiscal 1981 and the approximately $700,000 used to support it then will be freed for other chemical instrumentation programs, leading to an almost 23% increase in available funds.

Research funding would be up this year at the Department of Agriculture, too, 12%, to $871 million. Almost all of USDA's R&D budget is spent in three of USDA's numerous agencies. Most research is handled by the Agriculture Research and the Cooperative Research programs of the Science & Educational Administration. U.S. Forest Service research on forestation and water management and the Economics & Statistics work on data

The total federal R&D package

Agency by agency R&D funding breaks down like this

$ Millions	Obligations 1982[a]	Obligations 1981[a]	Obligations 1980[b]	Outlays 1982[a]	Outlays 1981[a]	Outlays 1980[b]
Defense	$20,033	$16,226	$13,943	$18,925	$15,874	$13,451
NASA	6,589	5,422	5,084	6,207	5,130	4,711
Energy	5,642	5,167	4,737	5,734	4,932	4,682
HHS	4,285	3,964	3,790	3,964	3,676	3,518
NSF	1,157	1,015	888	1,027	926	837
USDA	871	775	687	854	754	659
Interior	496	465	438	485	465	453
Transportation	474	413	374	424	387	377
Commerce	411	365	341	405	375	355
EPA	345	364	348	347	343	388
Labor	330	153	215	303	251	150
NRC	232	216	190	223	208	179
Agency for International Development	230	120	119	134	117	106
Veterans Adm.	163	147	133	155	140	132
Education	154	141	132	143	139	123
Other	324	273	264	320	289	269
TOTAL	$41,736	$35,226	$31,683	$39,650	$34,006	$30,390

a Estimates b Actual

Federal R&D funds to universities would climb 11%

$ Millions	Obligations 1982[a]	Obligations 1981[a]	Obligations 1980[b]	Outlays 1982[a]	Outlays 1981[a]	Outlays 1980[b]
HHS	$2354	$2185	$2076	$2213	$2007	$1961
NSF	868	761	666	807	708	620
Defense	639	528	451	608	503	430
Energy	351	312	293	352	310	291
USDA	283	241	221	272	238	206
NASA	204	188	171	184	169	147
Other	352	327	313	311	286	262
TOTAL	$5051	$4542	$4191	$4747	$4221	$3917

a Estimates b Actual

Funds for R&D facilities would rise a munificent 27%

$ Millions	Obligations 1982[a]	Obligations 1981[a]	Obligations 1980[b]	Outlays 1982[a]	Outlays 1981[a]	Outlays 1980[b]
Energy	$1763	$1410	$1021	$1718	$1382	$ 968
Defense	280	236	208	230	204	205
NASA	137	115	159	157	156	140
NSF	95	11	19	81	11	18
USDA	40	37	57	39	53	28
HHS	36	61	32	49	43	77
Other	88	53	64	76	65	57
TOTAL	$2439	$1923	$1560	$2350	$1914	$1493

a Estimates b Actual

collection and natural resource management take only about 21% of total USDA R&D funds, or about $184 million.

The remaining $687 million proposed for fiscal 1982 would be used to support research on food production, enhancement of natural resources, needs of regulatory agencies, tropical and subtropical agriculture, and beneficial uses of space technology.

Some proposed funding levels in the USDA agriculture research program include research on assessments of pesticide use and research on minor-use pesticides, to be increased 28% to $2.1 million; integrated pest management research, to be increased 6% to $8.5 million; and aerospace technology, up 30% to $6.5 million. Two new projects proposed for 1982 are studies of the effects of acid rain on agriculture, funded at $150,000, and the construction of another European biocontrol facility for $1.9 million.

Under cooperative research, the competitive research grants program, which awards grants for basic research on agriculture and human nutrition, is slated for a tremendous increase. An 81% leap to $29 million is proposed for these grants. However, a similarly large increase was requested last year, and Congress ended up cutting more than $9 million from the Administration's proposal, so approval of the total fiscal 1982 request is questionable.

Research efforts at the Department of Commerce also would be well funded in fiscal 1982. The overall R&D budget would rise 12.6% to $411 million, and basic research would rise 24% to $41 million.

Funding for the department's science and technical research budget, which funds the National Bureau of Standards, National Technical Information Service, Office of Productivity, Technology & Innovation, and the Office of Environmental Affairs, would increase almost 33% to $150 million. NBS alone would be in for a 26% increase to nearly $129 million. Of that amount $96 million, an increase of 14%, is earmarked for R&D programs.

Also included in the science and technical research budget would be $1.6 million for improved technology transfer, $5 million for strategic evaluation and assessment of innovation activities, $3.8 million to investigate innovative metals processing techniques, $3.0 million to develop measurements and standards for the automation of the discrete parts industry, and $5.2 million for Centers for Cooperative Generic Technology.

The R&D budget of the Department of Commerce's National Oceanic & Atmospheric Administration would be up $33 million, or 17%, to $229 million and would provide expanded support for research on acid rain pollution and on improved methods of detecting, tracking, and forecasting weather systems and violent storms.

The Environmental Protection Agency stands alone as the sole loser in Carter's proposed R&D budget. Assistant administrator William

NSF budget up a very nice 23.5% to well over $1.3 billion . . .

$ Millions	1982[a]	1981[a]	1980[b]
Mathematical and physical sciences	$ 301.1	$ 257.1	$227.0
Astronomical, atmospheric, earth, and ocean sciences	268.0	236.1	218.1
Biological, behavioral, and social sciences	219.0	198.1	185.7
Science and engineering education	111.9	80.7	77.2
Engineering	104.6	86.8	76.6
Cross-directorate programs	97.9	26.8	15.6
Scientific, technological, and international affairs	80.0	56.4	36.6
Antarctic program	70.1	64.7	55.8
Program development and management	67.2	61.7	58.2
Ocean drilling programs	30.0	22.0	19.5
Special foreign currency program	3.5	5.6	4.9
TOTAL	$1353.3	$1096.0	$975.2

a Estimate. b Actual. Note: Obligations.

. . . with funding for chemical research up 16% to $67 million

$ Millions	1982[a]	1981[a]	1980[b]	% change, 1981–82
Materials research	$ 88.5	$ 76.5	$ 68.7	15.7%
Physiology, cellular and molecular biology	84.3	77.7	72.1	8.5
Physics	83.6	72.2	63.4	15.8
Ocean sciences	81.0	75.0	66.3	8.0
Astronomical sciences	75.6	58.5	56.7	29.2
Atmospheric sciences	74.4	68.9	63.3	8.0
Chemistry	67.2	57.8	51.3	16.3
Environmental biology	44.7	41.1	39.7	16.1
Behavioral and neural sciences	43.6	39.6	36.8	8.7
Social and economic sciences	40.1	33.6	31.4	19.3
Mathematical sciences	34.4	28.2	25.0	22.0
Earth sciences	30.6	27.9	26.0	9.7
Computer research	27.5	22.4	18.5	22.8
Chemical and process engineering	22.1	18.1	16.0	22.1
TOTAL	$797.6	$697.5	$635.2	14.9%

a Estimate. b Actual. Note: Obligations.

NSF funding for chemical research breaks down like this

$ Millions	1982[a]	1981[a]	1980[b]
Structural chemistry and chemical thermodynamics	$14.07	$11.99	$10.79
Chemical dynamics	13.04	11.16	10.05
Chemical physics[c]	11.20	9.45	8.51
Synthetic organic and natural products chemistry	8.06	6.83	6.15
Chemical analysis	7.52	6.51	5.87
Synthetic inorganic and organometallic chemistry	7.41	6.36	5.72
Chemical instrumentation	5.95	5.55	4.23
TOTAL	$67.25	$57.85	$51.32

a Estimate. b Actual. c Formerly quantum chemistry. Note: Obligations.

EPA's 1982 R&D budget decreases 4%

$ Millions	1982[a]	1981[a]	1980[b]
Energy	$ 96.8	$ 106.6	$ 103.4
Air quality	68.5	69.5	68.4
Water quality	57.1	65.7	67.3
Toxic substances	38.8	36.5	30.9
Hazardous waste	32.0	29.6	13.1
Drinking water	30.4	26.8	23.0
Pesticides	7.5	10.8	12.9
Interdisciplinary	7.1	6.6	7.7
Management/support	4.0	4.1	5.5
Radiation	3.2	3.3	2.9
TOTAL	$345.4	$359.5	$335.1

a Estimate. b Actual. Note: Obligations.

Increases boost NASA R&D more than 20%

$ Millions	1982[a]	1981[a]	1980[b]
Conduct of R&D	$5452	$4342	$4089
Space shuttle	2230	1943	1871
Space flight operations	1043	684	447
Space applications	473	354	332
Physics and astronomy	451	345	337
Space tracking and data systems	435	341	332
Aeronautical research and technology	324	276	308
Planetary exploration	256	176	220
Space research and technology	141	111	116
Life sciences	49	42	44
Expendable launch vehicles	31	54	67
Technology utilization	15	12	12
Energy technology	4	4	3
Research and program management	1136	1081	996
Construction of facilities	137	115	159
TOTAL	$6725	$5538	$5244

a Estimate. b Actual. Note: Obligations.

NIH total funds increase a modest 5%

$ Millions	1982[a]	1981[a]	1980[b]
National Institutes	$3571	$3378	$3180
Cancer	1042	1010	998
Heart, Lung & Blood	596	564	527
Arthritis, Metabolism & Digestive Diseases	391	375	340
General Medical Sciences	362	336	312
Neurological & Communicative Disorders & Stroke	281	256	241
Allergy & Infectious Diseases	248	235	215
Child Health & Human Development	236	225	208
Eye	134	124	110
Environmental Health Sciences	118	104	88
Aging	86	77	70
Dental Research	77	72	68
Research resources	200	192	176
National Institute for Occupational Safety & Health	81	83	80
National Library of Medicine	51	49	46
Office of the Director	36	36	31
Research facilities	10	29	14
John E. Fogarty Center	10	9	9
TOTAL	$3959	$3776	$3533

a Estimate. b Actual. Note: Obligations.

Department of Energy civilian R&D budget rises a healthy 14%

$ Millions	Authorities 1982	Authorities 1981	Outlays 1982	Outlays 1981
Fossil energy	**$1530.5**	**$1084.0**	**$1399.3**	**$883.4**
Coal	**1388.9**	**931.9**	**1283.2**	**724.4**
Liquefaction	886.3	520.7	782.8	341.9
Gasification	226.9	169.3	226.4	138.0
Combustion systems	76.7	35.7	56.5	42.3
Advanced R&D	63.1	46.4	62.1	48.4
Environmental control	46.3	43.4	43.4	55.8
Mining R&D	32.0	48.0	50.4	35.4
Heat engines and heat recovery	29.0	36.4	35.3	38.1
Fuel cells	28.6	32.0	26.3	24.5
Petroleum and natural gas	**81.6**	**85.6**	**69.0**	**88.0**
Enhanced recovery	50.7	48.1	51.3	54.9
Oil shale	27.2	32.0	12.3	24.1
Advanced technology	3.7	5.5	5.4	9.0
Magnetohydrodynamics	**60.0**	**66.5**	**47.1**	**71.0**
Nuclear	**791.9**	**839.7**	**937.6**	**894.3**
Breeder reactor systems	**447.9**	**509.6**	**543.0**	**562.5**
Liquid metal	363.8	401.9	448.6	440.3
Water cooled	58.0	60.2	64.0	67.2
Fuel cycle R&D	26.1	47.5	30.4	55.0
Commercial waste management	**257.2**	**246.6**	**302.4**	**244.5**
Conventional reactors	**43.0**	**42.5**	**46.4**	**45.4**
Light-water reactors	28.0	35.0	31.8	35.5
Three Mile Island activities	10.0	6.5	9.6	8.7
Advanced reactor systems	5.0	1.0	5.0	1.2
Advanced nuclear systems	**43.8**	**41.0**	**45.8**	**41.9**
Space and terrestrial applications	40.8	38.0	42.6	38.9
Systems evaluations	3.0	3.0	3.2	3.0
General science and research	**605.9**	**508.3**	**598.3**	**509.0**
High-energy physics	415.6	352.2	409.6	354.6
Nuclear physics	136.5	110.2	136.8	110.8
Life sciences research	53.8	45.9	51.9	43.6
Magnetic fusion	**506.2**	**394.3**	**520.5**	**444.8**
Solar	**440.2**	**486.5**	**451.3**	**474.3**
Photovoltaics	161.5	160.2	161.8	142.9
Thermal energy systems	85.3	141.8	97.1	167.7
Wind energy systems	73.6	85.8	84.0	79.4
Biomass	56.0	46.4	34.0	44.9
Ocean energy systems	36.8	39.0	53.2	39.4
Alcohol fuels	27.0	13.3	21.2	—
Basic energy sciences	**308.0**	**243.9**	**308.6**	**253.6**
Materials sciences	118.2	95.1	117.8	105.8
Chemical sciences	84.0	67.9	85.0	67.0
Nuclear sciences	39.5	33.7	39.5	33.7
Engineering, mathematical, and geosciences	37.9	25.9	37.9	25.8
Biological energy research	10.0	7.7	10.0	7.7
Advanced energy projects	9.4	6.6	9.4	6.6
Inertial plasma physics research	9.0	7.0	9.0	7.0
Conservation	**304.4**	**276.0**	**288.4**	**257.9**
Transportation	121.7	107.7	108.0	97.1
Buildings and community systems	99.5	87.9	99.5	76.7
Industrial	51.6	53.9	51.6	62.5
Multisector	31.6	26.5	29.6	21.6
Environmental R&D	**280.1**	**236.8**	**274.5**	**229.8**
Geothermal	**91.6**	**156.0**	**121.6**	**158.3**
Energy storage systems	**59.5**	**71.9**	**64.0**	**74.3**
TOTAL	$4918.3	$4297.4	$4964.1	$4179.7

Note: All numbers are estimates

Drayton calls this "a hinge period" for the agency, a maturing period as it enters its second decade. And the agency enters its second 10 years "with the tightest budget" it has ever had, Drayton says.

Although this budget was a "very painful, very difficult" exercise, Drayton says, it highlights these facts: The environment is generally cleaner than it used to be; the agency has introduced new, more efficient ways of regulating; and EPA has turned its spotlight on toxic pollutants.

Still Carter's EPA budget proposes to move the agency into its second decade with only a modest 5% increase in total outlays, from $5.51 billion to $5.76 billion in fiscal 1982. Most of this increase is earmarked to enforce hazardous waste legislation. What the total figures don't show, however, is the 4% decrease in obligations for R&D.

The reduction in total R&D obligations from $360 million in fiscal 1981 to $345 million in fiscal 1982 reflects completion of major regulatory efforts, the agency says. For example, funding for air quality research would be dropped to $69 million in 1982, $5 million below 1981 outlays, largely because of a reduction in research on diesel particulates, other particulate and gaseous pollutants, and oxidants. Water quality research would be cut $7 million below 1981 levels, to $57 million. Of this reduction, $3 million is associated with a shift from "conventional" pollutant research to work on hazardous and toxic wastes.

The energy R&D program also is slated for a decrease of $11 million, to $102 million in 1982. Research in the upcoming year will focus on the environmental impact of the proposed synfuels projects in the West, and $9 million is earmarked for research on acid precipitation. Pesticide R&D funding would be slashed drastically, down $3 million to $7 million in 1982.

R&D programs receiving increases in 1982 reflect the agency's new efforts on toxic substances. Solid and hazardous waste R&D would increase $7 million to $32 million, and safe drinking water R&D would increase $2 million to $31 million. □

NOTE

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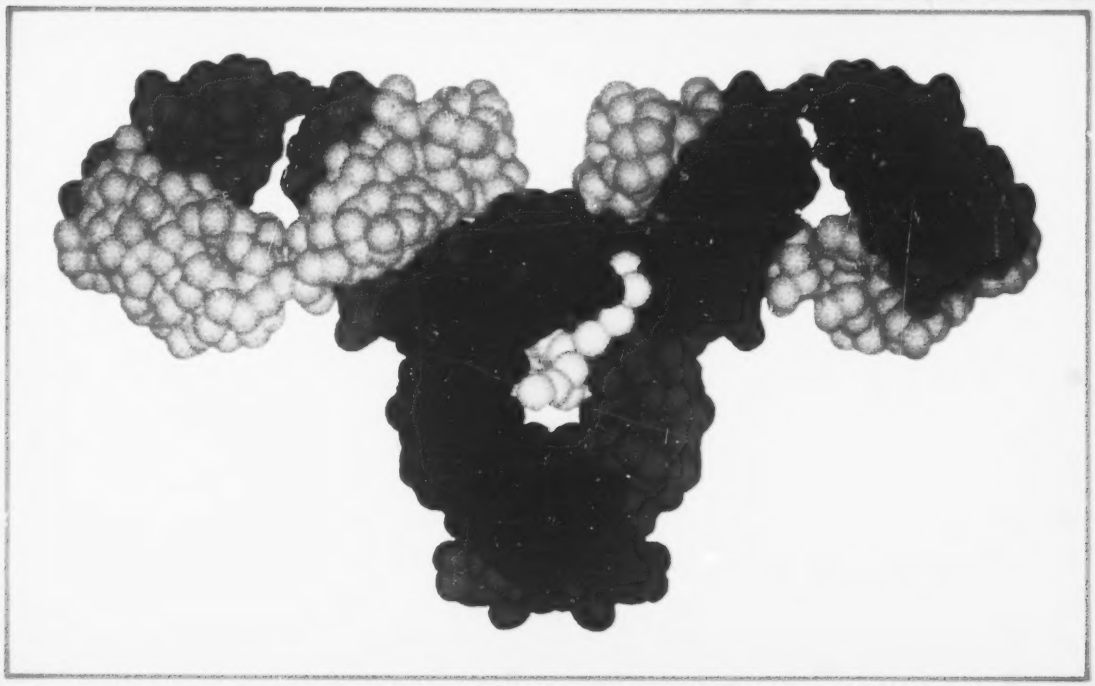

GLYCOPROTEINS

Research booming on long-neglected compounds that play vital biological roles Page 21

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Cover: Computer graphic display of Dob protein, a human IgG antibody, one of the first glycoproteins to have its three-dimensional structure determined. For color key to interpret structure, see page 21

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- ***Clues to the mystery*** *of Venus' swift, high-altitude winds and enveloping haze are emerging from Pioneer data.* ***Page 5***
- ***Demand for chemical engineers*** *this year is almost 10% higher than 1980 levels, salaries are up 13%, survey finds.* ***Page 5***
- ***Du Pont and PPG Industries*** *to study feasibility of joint venture to make ethylene glycol at Beaumont, Tex.* ***Page 5***
- ***NSF's programs on mineral processing*** *and extractive metallurgy consolidated in new Engineering Directorate.* ***Page 6***
- ***Engelhard may spin off*** *most of its chemicals and other industrial operations and become a trading organization.* ***Page 6***
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Business

- ***Foreign investment*** *for 10 leading U.S. chemical firms continues strong after assets reached $14 billion in 1980.* ***Page 8***

International

- ***England's Society of Chemical Industry*** *celebrates 100th birthday; has sections in Europe, Canada, and U.S.* ***Page 10***

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- ***Pinpointing barriers*** *to women and minorities in science, devising ways to overcome them is focus of new NSF panel.* ***Page 13***
- ***Joint Economic Committee study*** *on economic change muddied by political stamps of Capitol Hill participants.* ***Page 14***

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Glycoprotein research *is a very active area of biochemistry but elucidation of complex structures awaits refined, microminiaturized techniques.* ***Page 21***

ACS News

- ***New film available free*** *to ACS members teaching high school chemistry.* ***Page 46***

Pioneer data help explain Venus' winds

Scientists are getting close to solving one of the major puzzles of Venus' atmosphere, thanks to discoveries made during the past two years by the Pioneer Venus orbiter's close observation of the cloud-enshrouded planet. Cloud photos and polarimetry data from the orbiter indicate that Venus' global wind patterns change dramatically over a period of several years. Furthermore, the clouds are regularly enveloped by a high-altitude haze that appears and disappears also over several-year periods.

These findings could help scientists unravel the mystery of Venus' surprisingly swift equatorial winds. For a planet that rotates on its axis only once every 243 days and whose lower atmosphere is almost stagnant. Venus has high-altitude winds that whip clouds along at an astonishing 225 mph. This is 60 times as fast as the planet's rotation.

Wind speed measurements made by four Pioneer probes that entered Venus' atmosphere in December 1978 showed that the high-speed cloud-level winds are coupled to lower-altitude winds that also blow at high speeds. These winds could, in a general way, be explained as due to the transfer of momentum from the planet's slow-moving massive lower atmosphere to higher altitudes where the atmosphere is less massive so that the same momentum results in a much higher velocity.

But the latest Pioneer observations have discerned an intriguing motion pattern: The clouds and cloud-level winds rotate around Venus as if they were part of a solid, planet-encasing body. A natural consequence of this is that wind speeds are much higher at the equator than at the poles. This "solid body" wind pattern, however, was not observed in 1974 when the Mariner spacecraft flew past Venus. Apparently, National Aeronautics & Space Administration scientists conclude, the pattern of these wind changes in an irregular cycle perhaps several years in length.

The Pioneer orbiter has taken about 1000 photos of Venus' clouds and has made extensive measurements of the particles (primarily sulfuric acid) composing those clouds. NASA scientists expect it to continue sending pictures and data from Venus until 1985. □

Study shows high demand for chemical engineers

Current demand for chemical engineers places the discipline fifth in a ranking of the 10 leading engineering disciplines, according to a new survey.

The just-completed survey is an annual one conducted by Fox-Morris Personnel Consultants, Philadelphia, a major professional recruitment and executive search firm. The survey was conducted by the firm's 16 wholly owned offices from New York to Los Angeles and by 115 affiliates from coast to coast belonging to National Personnel Consultants.

A feature of this particular survey is that it measures only those engineering jobs and salaries actually offered and accepted in every major U.S. employment market.

In the first 10 weeks of 1981, the survey finds, overall demand for chemical engineers has surged 9.8% above year-ago levels, which were at a record high. Salaries being paid by U.S. employers in 1981 are averaging $22,600 for new B.S. chemical engineering graduates to more than $38,790 for senior chemical engineers in supervisory-level positions. The average for the high range of salaries—the top 20%—is $24,000 for new graduates, $32,000 for those with two to five years of experience, and $40,600 for those with management-level experience. The overall average increase in salaries for engineers in 1981 compared to a year ago is 13.6%.

The highest demand in every discipline is for engineers with two to five years of experience, according to Fox-Morris president Sanford L. Fox. New graduates are only slightly less sought after, he says. And at the senior experience level, the biggest demand is for experienced line- and middle-management engineers, needed to replace the professionals being tapped for top-level posts in their own companies and by competitors.

Fox-Morris notes that perhaps the biggest challenge confronting employers seeking engineering talent outside their own local areas in 1981 is getting engineers to move. The survey indicated that more and more employers are developing "creative financing" plans that include higher salary offers as well as mortgage takeovers and home-cost differential payments.

Another survey finding is a uniformly high demand throughout the U.S. for qualified female engineers. "Everyone seems to want them," Fox says. □

Chemical engineers are fifth in demand, second in salaries

Engineering degree/function	Demand increase for 1981 over 1980	Engineers, two to five years' experience	Average annual salary
Electronics/electrical	14.1%	Petroleum	$30,100
Control/instrument	13.9	Chemical	28,100
Mechanical	13.4	Electronics/electrical	27,800
Energy	13.0	Energy	27,650
Chemical	9.8	Mechanical	27,450
Industrial	9.6	Control/instrument	27,250
Research & test	9.1	Research & test	27,050
Petroleum	8.9	Metallurgical	26,300
Environmental/safety	8.8	Mining	26,050
Metallurgical	8.7	Industrial	25,400

Source: Fox-Morris/NPC U.S. Engineering Job/Salary Survey

PPG, Du Pont weigh ethylene glycol venture

PPG Industries and Du Pont will study the feasibility of a joint venture to produce ethylene glycol.

If the study indicates that the venture is a possibility, the two companies may well move an inactive ethylene glycol plant from Guayanilla, P.R., to Beaumont, Tex. The Puerto Rican plant, which has a capacity of about 400 million lb per year, has been shut down since November 1978.The shutdown was part of PPG Industries' halt of its Puerto Rican operations because of problems in getting feedstock from Commonwealth Oil Refining (C&EN, Nov. 20, 1978, page 10.) The Puerto Rican facility came on stream in late 1971.

The study for the two companies will be performed by an independent

Chemical investment abroad continues strong

Foreign assets of 10 leading U.S. chemical firms reached $14 billion in 1980, up 13.5%, and now account for 31.1% of their total assets

Overseas investment by the U.S. chemical industry seems to have increased further in the past year, based on data from 10 chemical companies that make up about 55% of U.S. chemical company sales.

Combined "identifiable foreign assets" of these 10 companies—Air Products, Allied Chemical, Celanese, Dow Chemical, Du Pont, B. F. Goodrich, Hercules, PPG Industries, Reichhold Chemicals, and Union Carbide—reached $14.1 billion in 1980, a 13.5% increase from 1979. On the other hand, total assets for the 10 companies, including those in the U.S., amounted to $45.5 billion by the end of 1980, a 10.1% increase from 1979.

Thus, foreign assets of the 10 companies increased more last year than their U.S. assets, which rose 9.0% to $31.4 billion in 1980.

Considering these 1980 increases, foreign assets now make up more than 31% of total assets of the 10 companies. In 1979 foreign assets accounted for about 30% of the total.

Dow Chemical, which has prided itself on its strong foreign business in the past few years, was far and away the leader in increasing its overseas properties last year. Its assets overseas increased about 26% to $5.5 billion last year. At more than 47%, these assets now make up almost half of the company's total, compared to 42% in 1979.

Foreign assets of three of the companies surveyed decreased in 1980. The biggest drop was for B. F. Goodrich, whose foreign assets fell 2.9% to $417 million in 1980. Reichhold Chemical's foreign assets declined 2.4% to $81 million during the year. And Du Pont's foreign assets decreased 2.5% to $2.27 billion.

Although combined foreign assets for these 10 companies increased healthily, their foreign business increased even more. Overseas sales, including exports, for the 10 companies surveyed increased 16.5% in 1980 to a combined $17.2 billion. Their U.S. sales increased just 7.9% to a total of $36.9 billion.

Thus, with overall sales at more than $54 billion in 1980 (up 10.6% from 1979), foreign sales of the 10 companies now make up almost 32% of total sales. This compares to just over 30% in 1979.

Once again, Dow is the leader in percentage of sales abroad. The company's $5.5 billion in overseas sales account for almost 52% of total company sales, an increase from about 51% in 1979.

However, two companies edged out Dow's 17.6% foreign sales growth in 1980 over 1979. Allied Chemical's foreign sales jumped 38.7% to $1.5 billion in 1980. And Air Products' foreign sales increased 27.8% to $344 million. B. F. Goodrich chalked up the smallest increase in foreign sales, 2.9%, bringing them to $648 million last year.

For the 10 companies, for each dollar of foreign assets, there was $1.22 in foreign sales. This amount is up from $1.19 in 1979. In fact, in 1979, the 10 companies averaged $1.19 per dollar of assets in both their foreign and U.S. businesses. In 1980, U.S. sales per dollar of assets fell to $1.18, creating a total companywide average of $1.19 for 1980. The largest ratio was at Reichhold Chemicals, with $2.14 in sales for each dollar of companywide assets; each dollar of its foreign assets returned $1.93 in foreign sales.

At the other extreme, Air Products' foreign sales amounted to just 77 cents for each dollar of foreign assets, and total sales just 81 cents for each dollar of total assets.

The caveat with these figures, however, is that instead of a high sales-to-assets ratio meaning that business has been good, it can mean that the company is running older, much more depreciated plants or that the company's export sales were larger in relation to sales from plants located at overseas sites.

William Storck, New York

Dow Chemical leads in foreign investment, with overseas assets totaling $5.5 billion

$ Millions	Foreign assets[a] 1980	% change from 1979	Total assets 1980	% change from 1979	Foreign assets as % of total assets 1980	1979	Foreign sales[b] 1980	% change from 1979	Total sales 1980	% change from 1979	Foreign sales as % of total sales 1980	1979
Air Products[c]	$ 447	20.4%	$ 1,751	23.3%	25.5%	26.1%	$ 344	27.8%	$ 1,421	15.6%	24.2%	21.9%
Allied Chemical	1,155	6.4	4,538	7.8	25.5	25.8	1,531	38.7	5,519	27.4	27.7	25.5
Celanese	493	4.2	2,634	10.7	18.7	19.9	760	13.1	3,348	6.4	22.7	21.4
Dow Chemical	5,450	26.4	11,538	12.5	47.2	42.1	5,493	17.6	10,626	14.8	51.7	50.5
Du Pont	2,268	−2.5	9,032	6.8	25.1	27.5	3,865	15.1	13,652	8.6	28.3	26.7
B. F. Goodrich	417	−2.9	2,000	5.0	20.8	22.5	648	2.9	3,080	3.1	21.0	21.1
Hercules	489	6.5	1,574	8.5	31.1	31.6	632	5.2	2,485	6.0	25.4	25.6
PPG Industries	451	14.5	2,826	7.2	16.0	14.9	661	16.2	3,158	2.1	20.9	18.4
Reichhold Chemicals	81	−2.4	414	−0.3	19.6	20.0	156	13.9	885	1.2	17.6	15.7
Union Carbide	2,882	14.5	9180	12.0	31.4	30.7	3,149	13.2	9,994	8.9	31.5	30.3
Total	**$14,132**	**13.5%**	**$45,487**	**10.1%**	**31.1%**	**30.1%**	**$17,239**	**16.5%**	**$54,168**	**10.6%**	**31.8%**	**30.2%**

a Foreign identifiable assets. b Foreign sales include exports. c For fiscal year ending Sept. 30, 1980.

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Demand for LPG feedstocks to surge in 1980's

Liquefied petroleum gases—propane and butanes—will find greatly increased use as chemical raw materials; imports could triple by 1990

Contrary to prevailing industry opinion in the mid-1970's, the 1980's are seeing a dramatic return to favor of very light, small-molecule hydrocarbon feedstocks for making chemicals, especially ethylene and other olefins. Although the big investments in new light-liquids-cracking olefins plants may be in huge non-U.S. natural gas fields—in Canada, Mexico, the Middle East, and other locations—the light liquids are headed for increased use in the U.S., too. Imports may account for just about all the gain.

A detailed forecast on the coming surge in light feedstocks in making U.S. chemicals is an important part of a general study of liquefied petroleum gases (LPG) by Carlton R. Jones of Pace Co. of Houston, presented at the annual convention of the Gas Processors Association in San Antonio, Tex. In practice, LPG means propane and butanes, although Jones also fills in the outlook for ethane.

Chemicals, Jones concludes, will be the major growth area in poundage for LPG this decade. Chemical demand for these light hydrocarbons will rise two thirds, from 268,000 bbl per day in 1980 to 446,000 bbl per day in 1990—an average of 5% per year. (An LPG barrel contains 42 gal.) In so doing, the chemical outlet will increase from 21% to 29% of total LPG demand, drawing to within reach of the traditional largest LPG outlet, the residential and construction market.

Chemical use of LPG will rise much faster than the overall LPG market. Jones says that demand for LPG will increase from 1.25 million bbl per day in 1980 to 1.54 million bbl per day in 1990. This averages only 1% per year and would be almost flat without chemicals.

Growth in chemical use of LPG will offset a large decline in LPG use in petroleum refining. Jones forecasts the drop here at 53%, from 210,000 bbl per day in 1980 to 99,000 bbl per day in 1990.

The biggest use of LPG in chemicals will remain feedstock for steam crackers making olefins, especially ethylene. Current estimates of ethylene demand and plant capacity indicate that need for new capacity will not be strong until the mid-1980's. But competitive feedstock costs and a declining supply outlook for feedstock ethane add up to a big increase in LPG feedstocks even without new plants.

Jones' cost figures show that butanes could have an advantage over naphtha, which enjoyed rising use in the 1970's, for making ethylene. For example, in 1990, *n*-butane could have a feedstock cost advantage of 2.5 cents per lb of product ethylene over the cost of naphtha. Operating costs and other components of ethylene's total selling price also would be lower for *n*-butane than for naphtha if *n*-butane partially replaced naphtha in steam crackers designed for heavy-liquid feedstocks.

Ethylene production units designed for heavy feedstocks usually cannot handle propane in any significant amount, Jones explains. However, *n*-butane can be substituted for part of the naphtha feedstock without additional capital expenses beyond those for butane storage.

Earlier this year, Pace surveyed heavy-feedstock ethylene plants on the Gulf Coast and found that, technically, they could use more than 135,000 bbl per day of butanes. Economics of butane availability and competition from other uses would affect the actual level of use.

Propane as a feedstock for making ethylene has ethane as its principal competitor. Plants designed to use light hydrocarbons as feedstock can handle either one to full capacity. Currently, ethane is dominant, and supplies of ethane continue to rise.

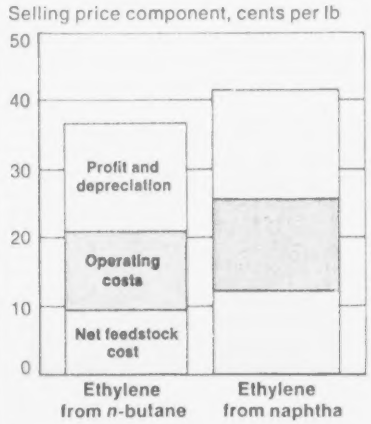
However, Jones forecasts that the ethane supply will decline during the 1980's for two reasons. Natural gas, the predominant source of ethane used in ethylene plants, will become "leaner." That is, it will contain lower amounts of hydrocarbons other than

Chemical use of LPG will grow 5% per year in 1980's

Uses	1977	1978	1980	1985	1990	% annual change, 1980–90
	Thousands of bbl per day					
Residential/ commercial	468	452	455	488	515	1%
Chemicals	216	241	268	405	446	5
Refineries	233	238	210	153	99	−7
Industrial/ agricultural	148	159	161	192	216	3
Synthetic natural gas/ utility gas	104	112	96	159	175	6
Transportation	74	66	68	77	85	2
TOTAL	1243	1269	1258	1474	1536	2%

Source: Pace Co.

Butane will cost less than naphtha feedstock in 1990



Source: Pace Co.

the basic methane—lower quantities of ethane, propane, butanes, and C_5 and higher hydrocarbons. At the same time, production of natural gas in the 48 contiguous states will decline. This means even lower availability of natural gas-based hydrocarbons.

Jones estimates that marketed production of natural gas from the 48 states will decline to 14 trillion cu ft in 1990 from 20 trillion cu ft in 1978. However, imports and production from unconventional sources such as coal are expected to keep total gas supply at about 22 trillion cu ft.

Under these circumstances, Jones forecasts the amount of ethane extracted from natural gas to decline to about 275,000 bbl per day in 1990 from 410,000 bbl per day in 1978. Such a decline will spur use of propane in steam crackers designed to use light hydrocarbons.

Most nonchemical uses of LPG will fare worse in the 1980's. The largest use will continue to be residential and commercial heating, whose share of total demand will decline slightly to 34% because of its slow growth rate.

The next largest nonchemical LPG market, refining, will be hit hard. The reason is a forecast decline in U.S. gasoline demand to 5.3 million bbl per day in 1990 from about 7 million bbl per day in 1979. LPG in gasoline is mainly butane, used as an additive to gain the right vapor pressure. Behind the decline in gasoline are increased mileage per gallon in new autos, slowed growth in total miles driven, and the rise of diesel engines, which may account for 20% of engines in new cars sold in 1980.

Jones estimates that the decline in refinery use of propane and butanes will continue throughout the 1980's, with about half the drop due by 1985. There are already signs that the slide is under way, in that a number of oil companies have announced closings of small refineries this year because of low capacity use. Hence, some refinery-bound LPG may be freed for chemical use.

In other LPG markets, Jones still foresees growth in the industrial-agricultural sector. The trend here will be about 3% per year from 1980 through 1990 to make this area the third largest LPG outlet, displacing refineries.

Fairly strong growth, about 6% per year on average in the 1980's, also awaits the synthetic natural gas/utility gas market for LPG. Jones sees the fastest part of this upswing coming by 1985, with growth averaging 11% per year for the next few years. This market was fairly flat in the late 1970's.

Even with the big drop in the gasoline market, LPG imports will have to grow substantially by 1980 to meet total LPG demand, Jones forecasts. He puts 1990 LPG imports at 475,000 bbl per day, up 271% from 128,000 bbl per day in 1980.

Pressure for the import bulge will come not only from a rise in the total LPG market but also from declines in the U.S. LPG supply from natural gas processing plants and from refineries. As U.S. natural gas production from traditional sources declines and the gas gets leaner, the amount of LPG from gas plants, which peaked in volume in 1978, will decline more than 10% in 1990 to 721,000 bbl per day from 806,000 bbl per day in 1980.

Because crude oil refining will remain about flat in this decade, LPG output from refineries also will hold about even. This volume was 324,000 bbl per day in 1980 and is forecast at 340,000 bbl per day in both 1985 and 1990. Hence, refineries will by 1990 be producing more than three times as much LPG as they will be consuming.

Canada, which currently accounts for 82% of imported LPG, will find its position slipping this decade as new gas-processing plants come on stream in Latin America, the Middle East, and Africa. By 1985, the share of LPG imports from Canada will decline to 28% of the total, Jones forecasts.

The biggest newcomer in LPG supply outside the U.S. will be the Middle East, especially Saudi Arabia. The Saudis' massive, multibillion-dollar gas-gathering project and attendant liquids separation plants will bring large supplies of propane and butanes to the world market in the next few years. By 1985, Jones forecasts that 110,000 bbl per day of Middle Eastern LPG will be coming to the U.S. In 1980, the figure was zero.

Similarly, the amount of African LPG coming to the U.S. will jump from zero to 50,000 bbl per day by 1985, Jones predicts. European LPG will go from none to 30,000 bbl per day.

The last major LPG source will be Latin America, Jones says. These imports will move from 23,000 bbl per day in 1980 to 95,000 bbl per day in 1985.

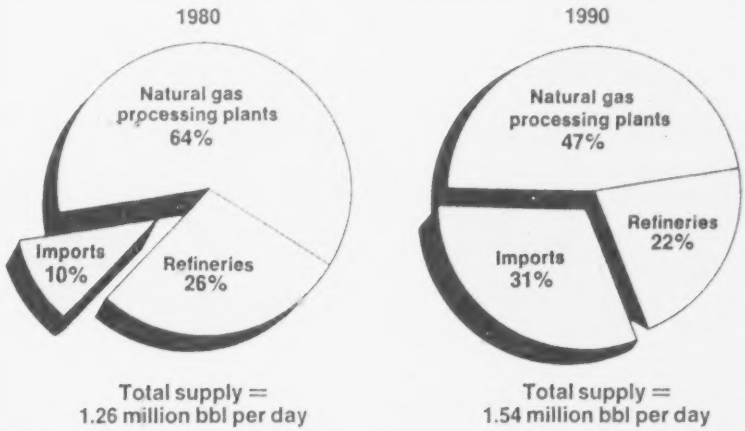
The logistics will change, too. Waterborne imports could reach 300,000 bbl per day by 1985 and possibly 425,000 bbl per day in 1990, Jones says. New receiving terminal projects are concentrated on the Gulf Coast. Jones expects no terminal capacity restraints. Some surplus capacity may even develop if all of the proposed terminal projects are built. □

Mideast will become big source of LPG for U.S.

Thousands of bbl per day	U.S. Imports 1978	1980	1985
Canada	86	105	110
Latin America	13	23	95
Europe	0	0	30
Middle East	0	0	110
Africa	0	0	50
Asia	1	0	2
TOTAL	100	128	397

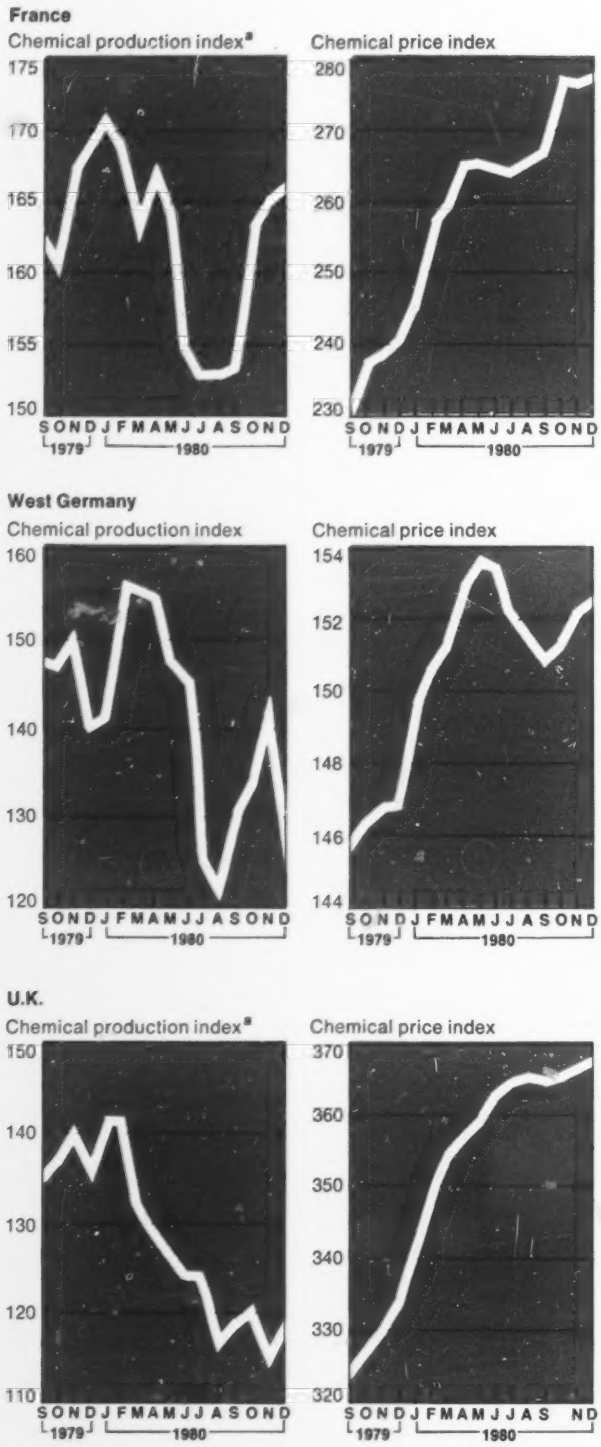
Source: Pace Co.

Imports' share of U.S. LPG supply will triple in 1980's



Source: Pace Co.

European chemicals outlook not bright



a Seasonally adjusted. **Note:** Base year for all indexes is 1970 = 100.

The near-term prospects for the West European chemical industry aren't bright. Some segments, such as pharmaceuticals and specialties, probably will continue to do reasonably well. But commodities will remain depressed. The consensus is that a general business upturn won't become apparent much before the closing months of the year, if then.

Production index data illustrate what occurred last year. (It's still too soon to get definitive figures for this year's opening months.) In France, for example, 1980 output declined 3% between January and December, in contrast to a 7% rise over the like 1979 period. For West Germany, the drop was closer to 9%, against a 5% increase in 1979. The contrast was more dramatic in the U.K. There, production index values slid more than 16%, all but wiping out 1979's 19% gain.

Put another way, the average production index rating in 1980 compared to 1979 was off 1.2% in France, 3.8% in West Germany, and 8.5% in the U.K., a stark reflection of the slowdown in demand for a host of chemical products. The slowdown prompted a number of companies to take units out of operation, in some cases permanently. And many of the units remaining in service have been running at levels ranging from 50 to 70% of their design capacity.

Companies have found it difficult to put through the level of price increases deemed necessary to cover their higher feedstock and operating costs, and to provide for future investments. In many instances, they have succumbed to the temptation to cut prices.

This shows up in the slackening off of the chemical price index growth. In France, the price index moved up 12% last year, whereas the increase was closer to 20% in 1979. West Germany's chemical price index rose 2% between January and December last year, well under the 12% advance the previous year. The pattern was similar for the U.K., where the price index for chemicals moved up 7% in 1980 compared to almost 19% in 1979.

European producers of bulk chemicals believe that their customers are ready to accept the arguments for higher prices. Dow Chemical, for one, has made a concerted effort "to restore business [in Europe] to a reasonable level of profitability," as Dow puts it. During this year's first quarter, Dow Europe raised the price of its ethylene glycol, for example, 16%, and of low-density polyethylene and general-purpose polystyrene 40%.

Mounting energy costs continue to be cause for concern to European chemical managers. The situation has become even more critical in the U.K. as the result of a clutch of higher taxes the government has imposed there following its budget a few weeks ago.

Prices paid for electricity, for instance, are of critical importance to the chlor-alkali industry. Imperial Chemical Industries claims that the price paid in the U.K. now is about twice the price paid in West Germany. In terms of total production cost, electricity accounts for some 80% of chlorine output, ICI notes. Consequently, U.K. makers of a wide range of downstream derivatives are finding themselves at a distinct disadvantage in the marketplace against their European competitors.

Dermot O'Sullivan, London

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Witco Chemical

Medium-sized firm gets a lot out of assets

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Cover: Fatty chemicals plant of Witco's Humko Chemicals division, Memphis

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Imports worry Japanese petrochemical makers

Sharp rise in imports of low-priced petrochemicals from U.S. puts pressure on industry constrained by high feedstock and energy costs

In the U.S., Detroit's auto makers and their political allies are worried about the flood of Japanese cars entering the country. But in Japan, chemical companies and many government officials are worried about the flood of petrochemicals pouring into Japan—much of them from the U.S.

True, Japan still has an overall trade surplus in chemicals. Last year, it exported an estimated $6.6 billion worth of chemicals and imported only $6.2 billion.

But the resulting $400 million chemical trade surplus is less than half of what it was in 1979. And it is a mere shadow of the $1.8 billion chemical trade surplus that Japan chalked up in 1975.

A big part of the explanation lies in the huge volumes of basic petrochemicals that are inundating Japan. It has Japanese petrochemical companies worried, because there is every indication that the import spree will not let up very soon.

Saddled with high feedstock and energy costs, and hampered by weak demand in passing through necessary price increases, the Japanese are starting to look at the import problem more seriously. Some companies are considering launching joint import efforts, and coupling this approach to production cartels. Meanwhile, the government is asking an advisory council to study ways of supporting basic materials industries that are threatened by increasing volumes of low-priced imports, particularly from the U.S. The petrochemical industry is one of them.

Japanese imports of U.S. chemicals have risen sharply over the past few years, increasing almost 50% in 1979 and jumping another 19% last year. Petrochemicals are in the forefront of the surge. Last year's $2 billion worth of U.S. chemicals moving into Japan is more than double what it was in 1977.

These imports put added pressure on Japanese petrochemical producers, however. With ethylene production costs there running at least 30% higher than they are in the U.S., ethylene producers' recovery after last year's experience will be difficult enough. They look upon growing imports of particular petrochemicals from the U.S. as an added impediment to recovery.

Some government officials, particularly within the Ministry of International Trade & Industry (MITI), are sympathetic. But some of them admit that Japan may have few options available to correct the situation. It's unlikely, for instance, that they can pressure the U.S. into voluntary export restraints on petrochemicals. The reason is that Japan is trying to encourage increased imports from the U.S. to counter the friction created by Japanese car shipments to the U.S.

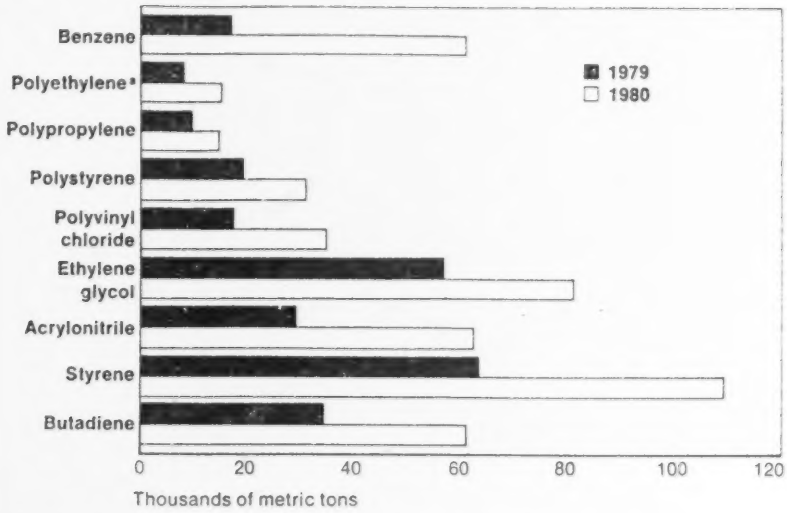
The government is asking a private council associated with MITI's Basic Industries Bureau to study the petrochemical import problem. One possible solution may be the approach now gaining support within the synthetic fibers industry.

Some Japanese fiber companies, including the giant Toray Industries, are urging that the industry band together to import fiber raw materials on a joint basis. Importing jointly, they say, will enable them to buy large volumes of raw material at favorable prices. In addition, they are urging that production of synthetic fibers and their raw materials be consolidated. Old, inefficient plants should be scrapped and production focused in new, high-productivity units.

Two fiber raw materials—acrylonitrile and ethylene glycol—are particularly thorny problems. Japanese imports of ethylene glycol, for instance, hit 80,866 metric tons last year, 42% more than in 1979. At the same time, Japanese exports of ethylene glycol plummeted 48% to 77,285 metric tons.

More than half of last year's imported ethylene glycol came from the U.S. This year, Japanese producers believe that imports will rise even further as additional Canadian material starts entering the Japanese market. Indications are that between 40,000 and 50,000 metric tons of Canadian ethylene glycol will be shipped to Japan this year. Even without any

Japanese imports of some major petrochemicals leaped dramatically last year



[a] Both high- and low-density. **Source:** Japan's Ministry of International Trade & Industry

other increases, this would put total glycol imports at 120,000 to 130,000 metric tons, which is equivalent to 25% of last year's ethylene glycol production in Japan.

Japanese companies also are being hurt by acrylonitrile imports. Import volume more than doubled last year to 62,946 metric tons whereas Japanese exports shriveled from 91,818 metric tons in 1979 to 19,265 metric tons last year.

As a result, Sumitomo Chemical recently became the first Japanese acrylonitrile producer to start importing the product independently. Sumitomo reasons that, because acrylonitrile imports probably will continue to increase anyway, it may as well take advantage of lower-priced U.S. material.

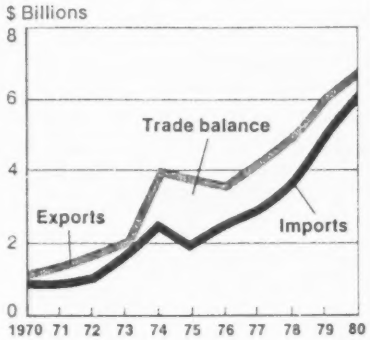
Japanese producers of fiber raw materials aren't the only ones feeling the pinch from imports. The situation is the same in polymers and their monomers. Imports of styrene, vinyl chloride, ethylene dichloride, polyethylene, and polypropylene all are problem areas for Japanese producers.

A report recently issued by Nomura Research Institute (NRI) underscores the extent of the problem. NRI notes that Japan imported 317,000 tons of 12 major petrochemicals in 1978. But it estimates that the import volume of these same 12 products will rise to 965,000 metric tons by 1985 and to a huge 1.56 million metric tons by 1990. In stark contrast, NRI believes that Japan's petrochemical exports in 1990 will shrink to one third its 1978 volume.

In terms of ethylene equivalent, 1978 imports accounted for only 7% of Japanese deliveries. But NRI expects this share to rise to 30% by 1990. Clearly, Japanese petrochemical producers will have some serious adjustments to make.

Earl Anderson, New York

Japan's chemical trade balance dwindles



Source: Japan's Ministry of International Trade & Industry

Execs bullish on chemicals outlook in 2000

Optimism for the future of the chemical industry was the dominant mood at the Society of Chemical Industry's centenary conference recently in Cambridge.

"Despite the present gloom, the next 20 years will be a very exciting and dynamic period for the industry," says William B. Duncan, SCI's president and a deputy chairman of Imperial Chemical Industries. "Although the future always looks gloomy from the bottom of a recession, not only may our worst fears not be realized, but our most optimistic hopes might even be surpassed."

Adds Robert Malpas, president of New York City-based Halcon International, "Even from the depths of the current recession, our industry looks healthy. The key is that demand for chemicals will continue to grow."

Duncan and Malpas were opening keynote speakers at the SCI conference, titled "The Chemical Industry—Problems, Opportunities, Resources." The 450 or so chemists from some 20 countries who were in the audience represented academia, government, industry, and learned and technical societies.

The industry's "ability to innovate and to adapt have served it in the past and can help it prosper in the future," Duncan notes. "The growth in the chemical industry since the Second World War has been fueled by the almost explosive burst of innovations in the period 1935 to 1950, followed by the vigorous exploitation of these new fields. A major cause of our recent failure to maintain the impetus of growth is the lack of really novel innovations since 1950. If we are to regain our past high growth rate in relation to the economy as a whole, we have to generate more innovations that lead to new businesses."

Duncan is quick to point out that "it would be misleading and far too facile to imply that innovation is the panacea for all our present ills. Moreover, innovation, by its nature, is risky, and we have to accept that not all projects we back will be winners.

"We must respond to today's overcapacity, rising costs, and underpricing by stringent attention to rationalization and improved productivity, which will increase profitability in the short term. We need to cut the cost of production sharply to generate profitable growth in existing businesses. With the increase in feedstock and energy prices, variable costs have become increasingly important for basic chemicals. For the next round of major investment in 1985 to 1990, we need to develop new processes which are substantially more efficient than current ones.

"There is urgent need to reduce capital costs to enable us to make the most of the limited funds available for investment. We shall require new chemical engineering technology that will enable us to design smaller, less costly plants."

Looking to changes in the pattern of world chemical output during the next 10 to 20 years, Duncan foresees "a tendency for the production of the most basic chemicals to migrate to gas- and oil-rich regions, particularly the Middle East. In the very long term, the industry will have to turn again to coal as a secure, reasonably priced source of feedstock and energy. Countries with large deposits of cheap coal, such as the U.S., South Africa, and Australia, could well become important centers for production of "petrochemicals" from coal.

"The changing pattern of world chemical production will lead not only to substantial growth in world trade, but to a sharpening of international competition," Duncan warns. "If the [present] industrialized nations are to reap the maximum benefit from this growth in world trade, they will need to export a larger proportion of high added-value chemicals. Value, not volume, must be the priority if we are to generate profitable export sales. Such business will provide the long-term growth and new employment opportunities for the late 1980's and the 1990's."

Halcon's Malpas presented the Cambridge conferees with a scenario of how the global chemical industry might look in 2000. According to this scenario:

- World chemical production will have doubled, or nearly so.
- The bulk of it, 77%, still will be where it is now—in Eastern and Western Europe, Japan, and the U.S.
- World trade in chemicals will have tripled.
- Feedstocks and patterns of trade in basic chemicals will change significantly.

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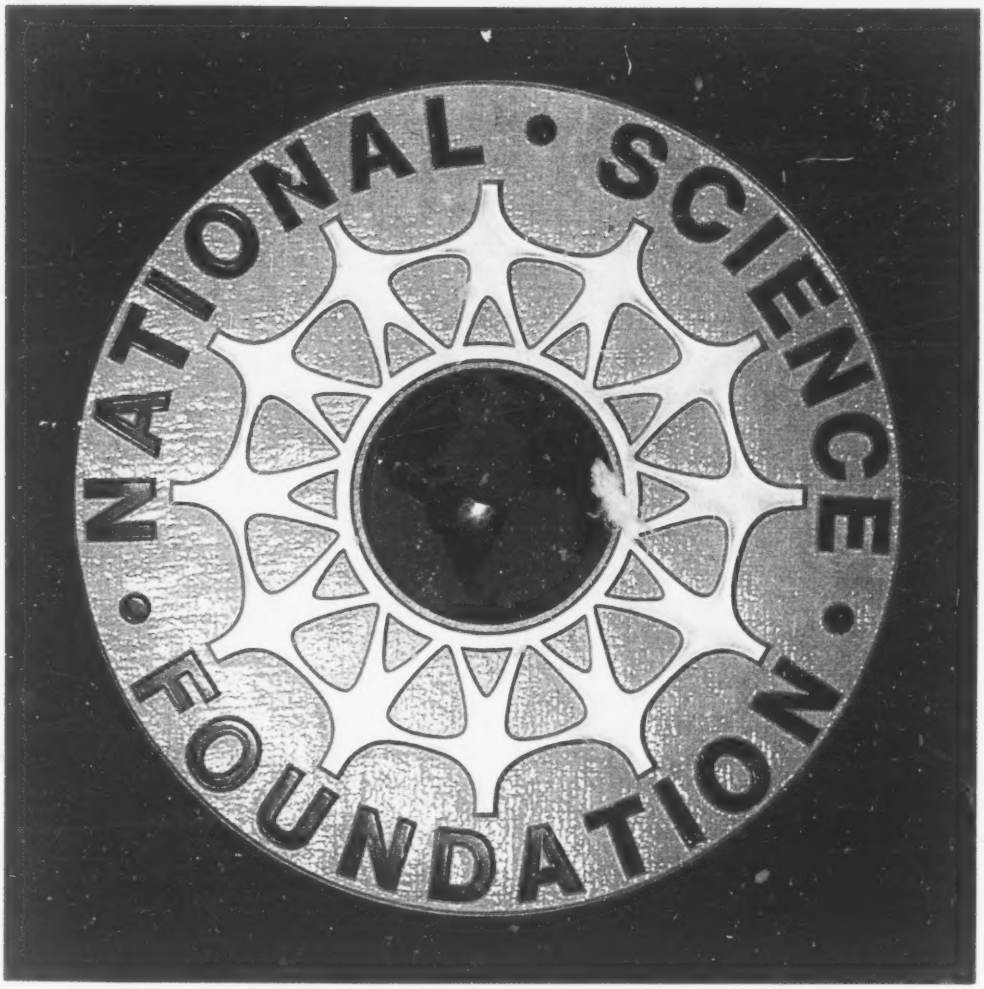

NSF after the budget cuts

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Chemical profits to rise in supply-side view

Using this analysis, chemical prices and profits are forecast to improve through 1982 because of relative decline in capital investment

The "supply-side" economics chic, which has wrapped Washington in proposals to stimulate industrial investment instead of consumer demand, is spreading. Now it has reached the chemical industry, at least in one leading Wall Street analyst's work.

Already a devoted follower of investment cycles in the chemical industry, Anantha K. S. Raman, managing director of First Boston Corp. of New York City, says that supply-side analysis of the chemical industry can provide insight into profit prospects not possible from more traditional demand-side analysis. This view contrasts with the view of many people in the chemical industry and the financial community who believe that the demand-side thinking ranks more important for a cyclical industry such as chemicals.

To Raman, supply-side logic says firmly that U.S. chemical prices and profit growth will be good through 1982. The main argument is that capital investment in chemical plants is growing relatively more slowly between 1979 and 1982 than it did between 1975 and 1978. This means that fixed-cost escalations remain more modest than when investment in new capacity is high. At the same time, the marketplace becomes more favorable for product price increases.

High capital investment in new capacity tends to have the opposite effect. Fixed costs then go up fast, and product price increases prove difficult, if not impossible; or prices actually may decline.

With such considerations, supply-side analyses focus on capital-investment cycles rather than on operating-rate or ordinary business cycles. Raman puts capacity expansions on an eight- or 10-year cycle, about double the ordinary business cycle. In the positive phase of the cycle, about half of it, very little new capacity is added. This keeps fixed cost increases relatively low and yields better conditions for price increases. In the following half of the cycle, the reverse occurs. Then the profit outlook becomes unfavorable.

Both fixed-cost escalations and marketplace conditions help indicate profit directions. For example, if operating rates drop because added supplies of a chemical become available through plant expansion, the effect on profit margins is more harmful than if operating rates drop because of lower demand.

The reason Raman considers the capacity-centered supply side more critical to profitability than the demand side is the concentration of productive capacity among the largest producers, leading to oligopolistic practices. For example, he estimates that in 1982, the top three U.S. nylon filament producers will have 81.3% of the total annual capacity of all nine producers. The four largest producers of high-density polyethylene will account for 45.9% of total annual capacity of 13 producers. The top three producers of caustic soda will have 52.5% of total annual capacity of 25 producers.

Pricing can be and generally is determined by the supply or producer side if the supply side has the ability or circumstances to risk lower operating rates as a possible penalty for higher prices without hurting profitability badly, Raman points out.

Raman notes that he lists general economic activity as a supply-side rather than demand-side pricing influence. What matters isn't demand itself but the perception of demand by producers. For example, Raman cites fertilizer as one of few products where demand influences pricing. In 1975, for example, farmers could not economically accept higher fertilizer prices because grain prices were not high enough. Farmers cut fertilizer consumption. Then fertilizer producers could have held on to their pricing, but they had unexpectedly high profits and resorted to price cuts when they could have held out.

Several other factors affect supply-side influence on prices besides expansions of capacity, concentration of production, and general economic activity. Among them are cost pressure, cost differentials between producers, and inflation expectations.

Fewer factors influence prices that are related to demand. Raman cites the number of customers and concentration, cost of money, inventories, price elasticity, and demand if suppliers are very capital intensive.

From these analyses, Raman concludes that a good environment exists now for the supply side, that is, chemical producers. In a modest economic growth period of 1979–82, he expects chemical prices to improve with excellent profit margins. His outlook for chemical commodities and chemical stock prices is good for the next few years. □

Capacity hikes will trail production gains in next few years

	Plant operating rate			% change			
				Plant capacity		Production	
	1974	1978	1982	1975–78	1979–82	1975–78	1979–82
Synthetic fibers	85.0%	85.7%	95.4%	16.7%	5.0%	15.2%	16.9%
Plastics	87.7	80.6	89.0	35.2	18.0	24.0	30.0
Organics	86.1	77.7	79.8	30.7	17.8	15.3	20.5
Inorganics	91.7	77.4	76.6	16.9	14.2	3.3	13.0
Fertilizer	87.0	83.9	94.1	37.2	4.9	30.9	17.6
TOTAL	**86.9%**	**80.3%**	**85.3%**	**28.8%**	**17.8%**	**13.4%**	**20.4%**
TOTAL, excluding fertilizer	**86.8%**	**79.6%**	**83.7%**	**27.0%**	**15.1%**	**15.1%**	**21.0%**

Note: Data are for 58 commodity chemicals. Operating rates are computed from annual average plant capacities. Physical quantities of each of the 58 chemicals have been weighted by their contribution to overall dollar sales. %-change figures over the four-year periods refer to the year before each period (1974 and 1978). Capacity data are as of Dec. 31, 1978. Production forecasts are as of February 1981. **Source:** First Boston Corp.

Developing nations exporting more technology

About two weeks ago, Alabama industrial development officials announced with considerable glee that the South Korean electronics giant, Gold Star Co., was building a plant in Huntsville for the assembly of color television sets. The event was only a further step in the penetration of once-poor countries into the technological world of the rich nations.

It is no longer surprising when a Japanese company sets up manufacturing shop in the U.S. But when a developing country begins doing the same thing, something important is happening in the global economy, signaling shifts in the way life is likely to be lived in the late 1980's and 1990's. If it's electronics today, will it be chemicals tomorrow?

Rich Asians and Arabs already are buying land and purchasing lumps of bank shares in the U.S. This isn't surprising. But when they begin exporting entire technologies—turnkey operations, if you will—history has taken one of those paradigmatic leaps.

India exports electric power stations, pharmaceutical plants, fertilizer complexes, and steel works. Argentina sells turnkey plants for producing cotton oil, refrigerated food, and processed fruit. Brazil finds foreign markets for plants making iron and steel, engineering equipment, and turbine equipment. The list is long and growing longer.

"Profound changes are working to modify the system of world economic relations," says a report just issued by the Paris-based Organization for Economic Cooperation & Development, "and technology transfers are part of these changes." Developing country industrialization, says the report, is a trend "dangerous to ignore or underestimate."

The report is called "North/South Technology Transfer: The Adjustments Ahead." It is the product of OECD's Ad Hoc Group on Technology Transfer headed by France's M. Turpin. Its conclusions are ominous to the U.S., which already has seen its technological leadership dwindle under competition from Europe and Japan. It is a factor that up to now has not been part of the dialogue on U.S. innovation policies.

Early signs, however, have been clear, most glaringly in the field of textiles. First it was Japanese textiles that caused anxiety in the U.S. textile industry before import quotas quelled the fever. Japanese labor costs were simply much lower than those in the U.S. Now, with Japanese labor costs rising to near parity with that of the U.S., the poorer countries offer the new competition.

"Price competition in standard products," says the report, "is likely to prove difficult when wage costs in the textile industry in some developing countries are one tenth to a quarter of average wage costs in OECD countries, and in the electrical and electronic industries equal to only half the wage costs in Japan."

Which of the developing countries offer the most significant threats? The obvious performers are Brazil, Mexico, South Korea, Taiwan, Hong Kong, and Singapore. Less obvious but logical comers are the oil-producing countries of Algeria, Libya, and Saudi Arabia, along with the more industrially mixed Costa Rica, Tunisia, Iraq, Malaysia, and Ghana. The first two groups already are functioning almost exactly like industrialized countries and the rest are fast developing the foundations for rapid technological growth. These account for 75% of industrial development in developing countries, according to the report.

The big question is how over the long run technological development in developing countries can improve economic health in the industrial world. The group says protectionism is self-defeating if free trade is the overall policy. Simply put, protectionism leads to economic warfare. The challenge is to adapt.

But how? Industrial countries want to export their technologies to developing countries. Exports of that sort mean big profits. But such exports also help the recipient countries compete over the long term with the exporting countries. Clearly, some new balance has to emerge.

OECD countries will plainly have to generate even more technology, but with better strategic planning. "Ways of improving self-financing and investment in industry must be sought," it says. "Efforts could also be made by governments to expand basic research on improving materials substitution, and to explore technical alternatives in such areas as 1) commodities, particularly on substitutes and recycling possibilities, 2) new forms of energy, and energy and materials conservation, simplified processes, and, where relevant, small-scale production."

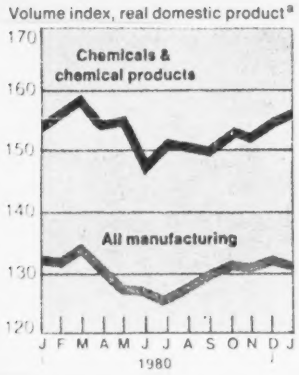
"This would make it possible," says the study, "to increase the number of projects that are sequentially implemented; to reduce capital costs associated with very large projects; and to further increase employment opportunities for the same amount of capital invested by increasing the effective competition rate and capital efficiency of projects." □

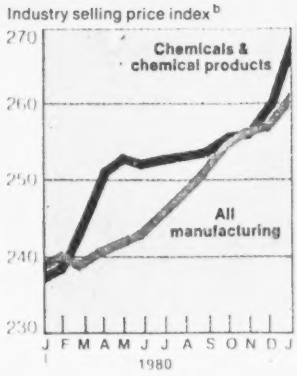
Chemical exports from developing countries to OECD countries are holding steady, while other products rise

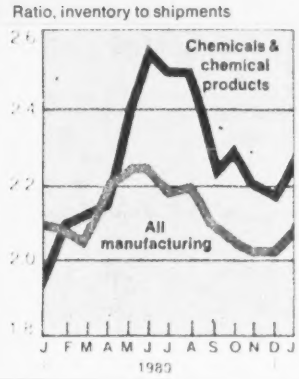
% OECD countries' imports from developing countries	1979	1978	1977	1976	1970
Chemicals	4.1%	3.8%	4.1%	3.9%	4.5%
Iron and steel	5.5	4.6	4.2	4.3	2.9
Textiles	20.5	19.8	17.0	17.1	13.0
Clothing	44.7	45.5	42.8	44.0	27.4
Footwear, leather goods and furs	33.9	34.5	31.6	31.9	16.4
Nonelectrical machinery	2.9	2.7	2.4	2.2	0.8
Electrical machinery and appliances	17.2	15.4	13.2	12.6	5.3
Road motor vehicles	1.1	1.1	0.6	0.6	0.2
Other transport equipment	5.5	8.2	5.3	3.9	2.0
Other manufactures	11.1	11.1	10.3	9.5	6.8
ALL MANUFACTURES	10.1%	9.9%	9.0%	8.7%	5.3%

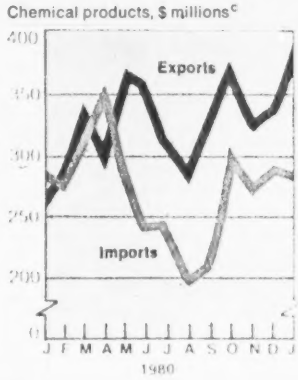
Note: From 1978, data not strictly comparable with previous years. **Source:** Organization for Economic Cooperation & Development

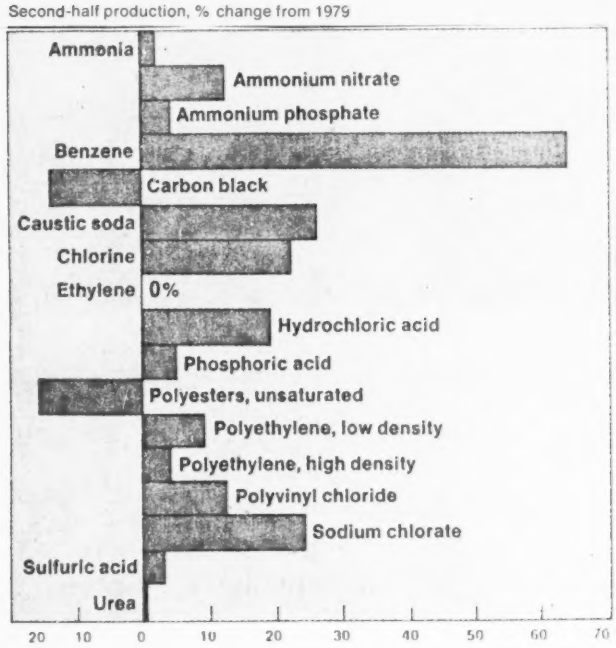
Prospects better for Canadian chemicals after so-so 1980











a Seasonally adjusted; 1971=100. b 1971=100. c Canadian dollars.
Source: Statistics Canada

For the Canadian chemical industry, 1980 was not a banner year. The worst came around midyear, when shipments lagged, inventories grew to mildly alarming levels, and earnings came under heavy pressure (C&EN, Feb. 16, page 18). Later in the year, things improved a little. As 1981 began, the key indicators were still no cause for elation, but at least they were moving in the right direction.

According to Statistics Canada, the chemical production index bottomed out in June, then began to rise slowly. By January 1981, however, it was still only 1.4% ahead of the year-earlier level. Nevertheless, the chemical industry outperformed the total manufacturing sector, which saw real output decline 1.2% during the same period.

Despite the general flatness of demand, production of some chemicals grew substantially during the second half of 1980. Benzene, caustic soda, and chlorine output all registered sizable increases.

However, other big-tonnage items, including ammonia, ethylene, urea, and sulfuric acid, showed little or no growth in the second half. Production of polyethylenes rebounded in the second half after a first-half decline. For the entire year, production was only marginally ahead of 1979.

After rising sharply at the beginning of the year, the industry selling price index for chemicals and chemical products leveled off at midyear, then resumed its inexorable climb at a slower rate. Prices jumped again as the new year brought new price lists; the January 1981 index was about 13% higher than the year-earlier index. The chemicals index outpaced the all-industry index, which rose only about 9% in the same period.

Chemical shipments declined during most of the first half of 1980; in June, even in inflated dollars, they were 13% below January levels. Throughout the same period, inventories increased steadily. The inventory-to-shipments ratio was a comfortable 1.97 in January. By June, it had risen to an uncomfortable 2.57. Thereafter, inventories held fairly constant as shipments picked up again, so that by December the ratio had dropped to 2.18. This ratio rose again in January to 2.27. The ratio for all-industry fluctuated similarly, but within narrower limits.

Foreign trade was a bright spot in an otherwise so-so year for the chemical industry. With a lot of new capacity and with access to lower-cost hydrocarbon feedstocks, Canada has become a factor to contend with in world chemical markets.

Overall, 1980 Canadian chemical exports exceeded 1979's about 20%. Exports of organic chemicals were up 31%; of fertilizers, 26%; of plastics and synthetic rubber, 27%. Even allowing for inflation, those figures represent significant growth.

Of course, Canada also still imports substantial amounts of chemicals. However, chemical imports increased only about 3% (in dollars) from 1979 to 1980. In real terms, that represents a decline. It appears that Canada will remain a net exporter of chemicals for some time to come.

Canada's chemical producers are guarded in their predictions of 1980 performance. They remain sanguine about long-term prospects, however. The chemical industry is, after all, Canada's fastest-growing major industry. This year, according to one source, capital expenditures will increase 72% from 1980 levels, to more than a billion Canadian dollars.

Ward Worthy, Chicago

Budget cuts pervade many NSF programs

Proposed reductions stop all science education support and curtail other programs, affecting chemistry and chemical engineering

David J. Hanson
C&EN, Washington

In the world of scientific research and education, no other federal agency has the influence or scope of the National Science Foundation. During the 30 years of its operation, NSF has evolved into one of the largest sources of funds for many scientific disciplines and is virtually the only source of support for research on science education.

The advent of a new Administration in Washington, D.C., this year—one with a different outlook toward science than the previous one—coincides with a time of economic uncertainty for the nation. A consequence has been the first really serious attempt to limit federal spending that many people can remember, including, for the first time in years, cuts from the budget of NSF.

Although it appears that federal support for basic research in the physical sciences and engineering will continue to increase as in recent years, a number of NSF programs, some set up to increase innovation and productivity and stimulate research, are being postponed or eliminated. Possibly of the greatest consequence is the Administration's move to end the long-time support of science education that has been a large part of NSF's role since the foundation was chartered in 1952.

According to officials at the Office of Management & Budget—the agency with prime responsibility for defending the Administration's proposed budget cuts—basic scientific research is an item that has to be supported. The Reagan Administration recognizes the strong responsibility the federal government has for basic science support and it recognizes the relationship between scientific progress and a healthy economy. When making budget cuts, therefore, instead of making across the board reductions, OMB set up priorities for NSF programs. This kept science and engineering support high, but meant the virtual disappearance of other programs. It also meant the end for a number of new programs before they could begin.

The end result is an NSF budget in which all science education support, except for continuation of fellowships already awarded, will be stopped. All so-called cross-directorate programs are to be halted, severe cuts are to be made in research support for social and behavioral sciences, and new or recently begun projects are to expire.

The negative impact of these changes, at least with respect to chemistry and chemical engineering, is not negligible. And the dropping of research funds for science education leaves a hole that no one seems prepared to fill. The directorate for mathematics and physical sciences is, on paper, slated for an 18% increase from fiscal 1981 to 1982 and funds for the newly formed engineering directorate, which includes chemical and process engineering, will increase 22%.

Richard S. Nicholson, head of the chemistry division at NSF, says that he is pleased with the increase his division is getting, but warns that the size of the increase is a little illusory. "One of the reasons the increase is so big," he says, "is because [OMB] reduced the size of our 1981 budget. So if you divide by the smaller denominator to calculate the increase, it obviously makes the percentage bigger.

"If you look at the average over a two-year period, then we look like about a 13% increase per year, which is good. The 18% increase is not really what it appears to be." In all, Nicholson believes the increase will allow his division to stay only about even with inflation.

The situation in chemical engineering is somewhat the same. Although basking in the sun after emerging as a full division from the reorganization of NSF engineering programs, Marshall M. Lih, head of the chemical and process engineering programs, still is pressing for more funds. His division is getting a 24% rise, according to the proposed 1982

Reagan's budget proposals show big gains for chemistry

$ Thousands	1980[a]	1981[b]	1982[b]	% change 1981–82
Chemistry	**$51,450**	**$55,860**	**$65,920**	**18%**
Structural chemistry and thermodynamics	10,736	11,987	13,840	15
Chemical physics	8,542	9,453	11,040	17
Chemical dynamics	10,149	11,159	12,840	15
Chemical analysis	5,886	6,514	6,990	7
Synthetic inorganic and organometallic chemistry	5,743	6,357	7,290	15
Synthetic organic and natural products chemistry	6,170	6,830	7,970	17
Chemical instrumentation	4,225	3,560	5,950	65
Chemical and process engineering	**$15,980**	**$17,500**	**$21,730**	**24%**
Kinetic catalysis and reaction engineering	2,488	2,800	3,530	26
Chemical and biochemical engineering processes	2,468	3,210	3,930	22
Engineering energetics	2,484	2,979	3,630	22
Thermodynamic and transport phenomena	3,074	3,171	3,830	21
Particulate and multi-phase processes	2,035	2,130	2,940	38
Separation processes	1,430	1,310	2,060	57
Mineral processes	755	950	1,000	5
Renewable materials engineering	1,246	950	810	−15

a Actual. b Reagan Administration revised budget. Source: National Science Foundation

budget, or about 18% per year averaged over the past two years. Still, Lih says, he gets so many grant proposals, he can't accept that his renewal rate is less than 50% compared to an almost 80% renewal rate for the chemistry and some other divisions.

"We're trying to spread the money around as much as we can," Lih says, "but we're always asking ourselves if it is better to support the established researchers, or give the new ones support."

A particular problem for these divisions is getting enough money out for equipment. When the chemistry division was told it had to trim $2 million from its fiscal 1981 budget, it all ended up coming out of the equipment category. "We stopped the equipment grants program right in its tracks," Nicholson says. "We thought this would be the least disruptive way, as these grants do not carry any personnel with them. We did not do it because equipment is low priority, but because it seemed the most rational way to deal with a short-term cut. If we get the big increase in 1982, we will carry over strong proposals from this year to that year."

Lih says he is stretching to the limit what he can give for equipment purchases. About $2.6 million, or 17% of the total, from his division went for equipment in 1980. Half of this was tucked inside normal research grants and the rest went for specialized research equipment awards, which, like the chemistry equipment grants, carry no personnel charges. The problems of trying to teach with antiquated and broken equipment are particularly bad in chemical engineering (C&EN, Feb. 9, page 43).

A new program, set up to begin in 1982, had been planned to help out this equipment crunch. This was a $75 million fund to modernize university research equipment and facilities. Not separated into various disciplines, the fund was to go to the most needy, with the priorities set by the universities. That program has been removed completely in the Reagan proposal. The money had been part of a $300 million budget adjustment for science set up by the Carter administration. The $225 million which did not go to NSF was spread around other science-funding federal agencies.

But new programs were not the only NSF areas that were mauled or killed in the budget cuts. The industry/university cooperative research project, an interdisciplinary approach to stimulate productivity, was to triple its funding above fiscal 1981 levels. The Reagan plan calls for a $6 million rescission or cutback in 1981 funding, back to about $8 million, and then a more moderate rise to $9.4 million in 1982. In 1980, the chemistry division received 11% of the $5 million IUC budget, and chemical engineering more than 20%.

Nicholson: size of boost is illusory

Another program that funds chemical and chemical engineering facilities is the regional facilities instrumentation program. Begun in 1978, this project funds 14 regional labs at major universities throughout the U.S. At $2.7 million, it's not a large spender, but its large instrumentation capability is used extensively by scientists from all disciplines. If its funds are not restored, it faces the choice of being phased out or of taking a little grant money from the other research areas, something the division heads really don't want to happen.

So it looks as if basic research in the physical sciences and engineering, with the exception of some equipment funding and the loss of the cross-directorate programs, will just about be able to hold the status quo, though these programs will not have a chance to start anything new. A bigger problem, if the Reagan proposal is accepted as submitted, is the virtual elimination of all of the foundation's science education programs.

From the start, education has been a major part of the mission of NSF. When first funded in 1952, education obligations were 44% of the total NSF budget, though only $1.54 million. Science education funding reached a peak in 1968 when more than $134 million went to education programs and graduate fellowships. This funding leveled off in the 1970's at about $70 million, but it was beginning to rise again during the Carter administration. It was supposed to get $112 million in the original 1982 budget proposal.

Some argue that public support for science education can be framed by two distinct events. The first would be the launching of the artificial satellite, Sputnik, by the Soviet Union in 1957. This effectively triggered an intensive effort in the U.S. to improve the quality—and quantity—of its science education programs. And the effort was successful. One educator who worked in science education during that time says the U.S. had the best science instruction in its history during the 1960's.

The second event was the introduction in the early 1970's of a social studies program designed by NSF for tenth-grade students. Called Man: A Course of Study, it explained cultural differences in groups around the world, but was met with vehement anger by the public. Complaints about teaching children unacceptable values and of interfering with private enterprise resulted in drops in science education funding at NSF from which the agency was only recently beginning to recover.

Now, in the name of fiscal restraint, the Reagan team has done away with the education funding altogether. Claiming that science education is a low-priority item for federal funding, that NSF directorate has been cut back to $9.9 million for fiscal 1982, just enough to continue funding the graduate fellowships it already has awarded. Other ongoing projects, including local science course improvement, instructional science equipment, public understanding of science, information dissemination for science education, minority institution science development, and more are eliminated.

Perhaps of all the programs available at NSF for cutting, the education directorate was particularly vulnerable. It had not had a permanent leader since April 1980 when assistant director F. James Rutherford took a position at the Department of Education. Also, when these cuts were being planned, NSF itself was in the midst of changing directors with the arrival of John Slaughter to succeed Richard C. Atkinson. So there may have been no strong leadership voice in the directorate with the authority, political access, or influence to dissuade the budget cutters from their course.

OMB staffers are sanguine about the change. The rationale for the cuts

is that science and engineering research are the prime recipients of funding, and education is not. OMB believes that the NSF programs were not handling the long-term education problems sufficiently and that they did not provide enough leverage to change the educational patterns in the U.S. It stresses that the $80 million invested by NSF gets swallowed up and lost in the magnitude of the $140 billion spent annually on education in the U.S. The place for education support, according to the ideology of the Administration, is at the local and state level, because local programs can improve science education more effectively.

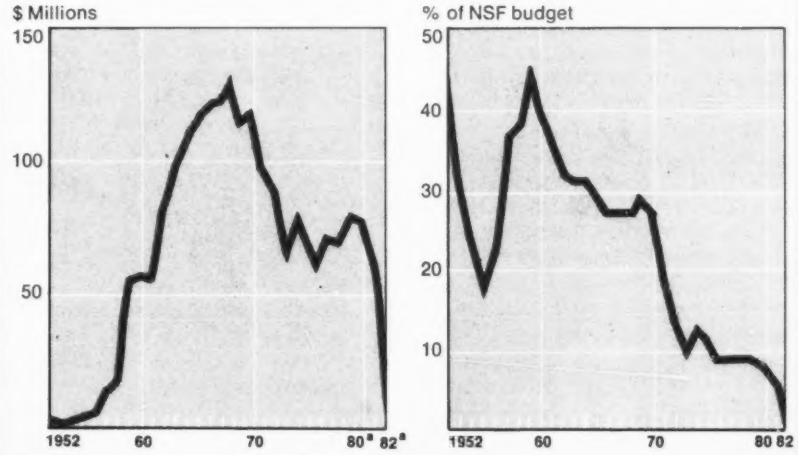
Much of this runs counter to what educators in science and mathematics have been saying about the need for science education support. Bill G. Aldridge, director of the National Science Teachers Association, says that science education will be insignificant and lacking substance unless there is substantial intervention, particularly at the national level. NSF director Slaughter, in a speech at the American Association for the Advancement of Science meeting this year (before the budget cuts), said that the U.S. continues to be confronted with an urgent need to reinforce science and mathematic education. Rutherford, commenting on the effects of the proposed science education cuts, says it will be a disaster. And, a large joint study by the Department of Education and NSF completed this past fall—Science & Engineering Education in the Eighties—lists numerous problems in the teaching of science and mathematics in the U.S.

Supporters of the science education programs say that when looking at the NSF programs, admittedly small, it is easy to underestimate the impact that they have. The NSF programs frequently are described as catalysts, with the ability to cause additional kinds of action, whether it be increased faculty or campus activity in science, or the attraction of some kind of state or local matching education funds.

Federal government support for science education programs also is viewed as symbolic. Pulling out support for science education, NSF supporters claim, could be taken as a sign to local governments that the federal government does not consider science education important enough to worry about. State governments frequently are even more strapped for education funds than the federal agencies, so the result could be no money at all for improving science teaching, when there had at least been a little before.

Science education was not the only effort supported by NSF that caught the attention of the fiscal restrainers. The plight of women scientists and minorities has been the subject of an increasing number of projects to encourage and support their participation. For the most part, these projects have been eliminated under the Reagan plan. The research improvement for minority instructions program, integrated basic research programs, and an experimental program to stimulate competitive research all are scheduled to be dropped. In addition, new programs designed to help women and minorities get research grants have been stopped.

Education spending at NSF has been falling since the 60's



a Proposed in Reagan budget. **Source:** National Science Foundation

OMB maintains that the goals of these NSF programs can be satisfied by other means. In the areas of competition of women and minorities for research funds, for instance, it is thought that women have become effective enough to get the grants on their own merits. And, although it perhaps should not have to be said, the presence of Slaughter, a successful black scientist, as head of NSF, assures that the foundation will be sensitive to minority needs and encourage their participation through its basic research support programs.

The ultimate decision on how NSF will be funded rests, of course, with Congress. So far, the lengthy deliberations leading to that decision have barely begun. The House Subcommittee on Science, Research & Technology has held hearings on the proposed NSF budget at which all nongovernment witnesses requested restoration of some parts of the funding. In the end, that panel voted to increase the total budget, adding $26 million to the biological, behavioral, and social sciences, restoring $13 million for cross-directorate programs, and bringing the education directorate back up to $75 million. Although other House committees will alter the proposals to suit themselves, the indication is that, in the House at least, some efforts likely will be made to restore the forsaken programs.

Consideration of the NSF budget has just barely begun in the Senate with the meeting of Sen. Orrin Hatch's (R.-Utah) Committee on Labor & Human Resources. Although Hatch's sympathy is with many of the NSF programs for which drastic cuts are proposed, the committee is facing the constraint of a recent Senate budget resolution that would permit only about a $15 million increase to the entire $1.033 billion NSF budget. At present, it does not appear likely that the Senate will try very hard to overreach that limit.

One serious possibility being discussed for saving the education programs would be simply to trim the large increases given to the physical sciences and engineering and put the savings toward science education. It's easy to see that, with other areas so decimated, these could become likely targets, and this solution would be easier than adding large sums to the budget. As one Senate staffer puts it, it is hard politically to explain how you can vote for cuts in child nutrition, but add money for something as indirectly beneficial and esoteric as NSF. □

NOTE

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NEWS

April 27, 1981

Major pigments struggle for recovery
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Shuttle [illegible]
opens [illegible]
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space Page 17

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Chemical & Engineering NEWS

Cover: Space shuttle orbiter *Columbia* takes off from Kennedy Space Center, Cape Canaveral, Fla. Photo courtesy of NASA

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- ***Economic recovery may be beginning in the U.K.;*** *first-quarter reports from industry and government show production gains, earnings improvements.* ***Page 5***
- ***Recent genetic engineering achievements*** *include production of interferon in Bacillus bacteria; OTA releases report on the impacts of applied genetics.* ***Page 5***
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CHEMICAL EARNINGS RESUMING DECLINE

Based on earnings reports from a number of U.S. chemical companies, it now looks like last year's fourth-quarter increase in profits was merely a pause. In the first quarter this year, earnings have resumed their decline.

Reports from 25 of the 40 largest chemical companies in the U.S. show that earnings in the first quarter have dropped an average of 9.0% to a combined total of $1.48 billion from the same period a year ago. At the same time sales among the 25 companies have risen just 6% to about $23.4 billion.

Consequently, profitability is falling rapidly among the 25 companies. Average profit margin (net earnings as a percentage of sales) among the group dropped one full percentage point to 6.3% in the first quarter this year from 7.3% in the first quarter last year.

The economic indicators had predicted that the first quarter would not be very good. Chemical production has been relatively flat for the first two months of the year, and shipments of chemicals have followed suit. Prices are higher than they were both in the fourth and first quarters of 1980, but their rate of rise has slowed considerably from what it has been in spite of a broad range of price increases in January.

In fact, the January increases in chemical prices may have hurt the first quarter more than they helped. Reports from the industry at the time indicated that there was much buying in December in advance of the January price hikes. In effect, one could thus say that some of the first-quarter results were moved back into the final quarter of last year.

Companies have been quick to complain about physical volumes in the first quarter. At Union Carbide William S. Sneath, chairman and chief executive officer, says that product demand dropped in the first quarter.

Du Pont says that in the U.S. sales rose 8% over first-quarter 1980 levels; of this, 4% was on selling price increases and 4% was on volume increase. Dow Chemical also indicates that total volume was flat.

And at Rohm & Haas, chairman Vincent L. Gregory Jr. says that the physical volume of shipments was even with levels in the first quarter of 1980. Volume was up 2% in the U.S. but in Europe fell 10% from first-quarter 1980 levels.

Western Europe, and the declining economies there, was of concern to many. Du Pont says that international earnings for the first quarter were 19 cents a share compared with 60 cents a share in the first quarter last year. The reasons cited for the decline include the slowdown in European economies, adverse impact from the strengthening U.S. dollar, and difficulty in raising foreign selling prices to cover costs.

Paul F. Oreffice, president of Dow, said that "business conditions, especially in Europe, did not meet our expectations in the first quarter, and we've got some catching up to do." Oreffice says that Dow Chemical Europe's earnings were off more than 30 cents a share in the first quarter, accounting for more than half of the company's total earnings decline. The major factors in the drop were severe price competition and higher costs. Oreffice also cites the strengthening dollar.

At Celanese, non-U.S. fibers and chemicals businesses lost 17 cents a share in the first quarter this year, compared to a net profit of 36 cents a share in the first three months of 1980. The company blamed fibers weakness in Brazil, Colombia, and Europe.

And Air Products indicates that industrial gas sales in Europe continue to be depressed because of the recession there.

Profits are resuming their fall in the first quarter

	FIRST QUARTER							
	Sales			Earnings[a]			Profit margin[b]	
$ Millions	1981	1980	% change	1981	1980	% change	1981	1980
Air Products	$ 413.0	$ 378.0	14%	$ 36.9	$ 34.2	8%	8.9%	9.0%
Akzona	308.8	293.2	5	2.7	5.3	−49	0.9	1.8
Allied Chemical	1582.0	1384.0	14	84.0	68.0	24	5.3	4.9
American Cyanamid	887.0	830.0	7	47.1	38.0	24	5.3	4.6
Celanese	911.0	847.0	8	67.0	59.0	14	7.4	7.0
Diamond Shamrock	865.0	755.3	15	48.0	56.3	−15	6.5	7.5
Dow Chemical	2896.9	2809.5	3	128.9	230.5	−44	4.4	8.2
Du Pont	3654.0	3568.0	2	201.0	239.0	−16	5.5	6.7
First Mississippi	64.2	42.1	52	0.4	4.9	−92	0.6	11.6
Freeport-McMoRan	224.7	163.7	37	49.0	43.1	14	21.8	26.3
B. F. Goodrich[c]	780.4	767.5	2	8.3	16.8	−51	1.1	2.2
W. R. Grace	1489.1	1369.5	8	83.0	65.8	26	5.6	4.8
Great Lakes Chemical	34.8	34.0	3	5.3	5.3	nc	15.2	15.6
Hercules	667.0	646.0	9	35.5	33.7	5	5.3	5.2
International Minerals[d]	563.2	459.5	23	47.0	55.0	−15	8.3	12.0
Monsanto	1900.0	1822.5	4	176.0	164.2	7	9.3	9.0
Olin	521.7	478.1	9	28.4	22.1	27	5.4	4.6
Pennwalt	295.0	296.0	—	7.7	11.4	−32	2.6	3.9
PPG Industries	809.4	797.4	2	52.5	54.7	−4	6.5	6.9
Rohm & Haas[e]	478.7	435.7	10	27.4	27.1	1	5.7	6.2
Stauffer Chemical	629.0	583.0	8	87.9	69.6	26	13.9	11.9
Texasgulf[f]	275.3	280.0	−2	66.3	77.5	−14	24.1	27.7
Thiokol	172.5	147.4	17	8.5	9.9	−14	4.9	6.7
Union Carbide[g]	2639.6	2565.6	3	178.0	219.9	−19	6.7	8.6
Witco Chemical	323.5	285.6	13	5.9	10.5	−44	1.8	3.7
TOTAL	$23,385.8	$22,038.6	6%	$1482.7	$1621.8	−9%	6.3%	7.3%

a After-tax operating income exluding extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales. c Excludes nonrecurring gains of $3.5 million in first-quarter 1980 and $18.0 million in first-quarter 1981. d Excludes nonrecurring charge of $14.0 million in 1980 figure. e Excludes $4.4 million in nonrecurring gains in first-quarter 1981. f Excludes nonrecurring gains of $39.1 million in first-quarter 1980 and $18.6 million in first-quarter 1981. g Excludes nonrecurring credit of $217.3 million in first-quarter 1980. nc = no change.

One of the most important items coming out of the companies' first-quarter statements is the weakening of fertilizers, especially phosphates. For some time, fertilizers have been performing well and, since they did not go into decline with much of the rest of the chemical spectrum, fertilizers had been propping up earnings to some extent for the last nine months of 1980. However, this may be changing as phosphates begin a decline brought on by lower exports and less U.S. demand.

American Cyanamid this quarter posted lower sales and operating earnings in the fertilizer and antibiotic feed businesses. The company says that there was a significant drop in both U.S. and export demand for phosphate fertilizers.

First Mississippi says that fertilizer operating profits were down because of lower diammonium phosphate sales following record volumes last fall. And Freeport-McMoRan (formerly Freeport Minerals) called its phosphoric acid and fertilizer markets "disappointingly weak," particularly abroad.

The weakening of the phosphate market is causing concern among more than just the companies that produce the products. In its latest "Chemical Industry Estimate Summary," Oppenheimer & Co., the New York City investment house, expresses both concern and bewilderment. The summary says: "The cause of the weakness in the DAP (diammonium phosphate) and acid prices has not been clear. The most popular explanation is the embargo on acid shipments to the Soviet Union. Few observers expected the embargo to last as long as it has, and those that did thought the Soviets would manage to obtain their supplies elsewhere." According to Oppenheimer, the net result has been that 5% of U.S. production is "looking for a home" and holding back prices.

That seems to account for the flat merchant phosphoric acid prices, but it does not account for the 15% decline in diammonium phosphate prices, Oppenheimer says.

Besides phosphate fertilizers and weak European markets, the U.S. companies say that earnings declines were prodded by plastics in the first quarter.

However, the good news is that fibers, long in the doldrums, are starting to turn around. Of the companies that have reported thus far and that produce fibers, all have seen improvement in their fibers operations over the first quarter of last year. □

U.K. economy may be starting to recover

After an unrelenting string of dismal economic reports over the past year, the news from the U.K. has suddenly brightened. First-quarter reports from the government and chemical companies have taken a swing up, hinting that a recovery may be in the works. If so, it would be music to the ears of U.S. chemical executives as well, who have had to give shareholders some pretty depressing news on foreign earnings in the past week.

From the U.K., the government has reported the first rise in production since Britain's recession began last year. From the corporate side, Imperial Chemical Industries, the U.K.'s largest chemical company, said at its annual meeting that first-quarter earnings should be improved after a loss in 1980. March seems to have begun a sales pickup for ICI after a poor January and February.

In the U.S., another measure of the U.K. economy points toward the same trend as the hard news from ICI and the British government. The Conference Board of New York City says that its series of international leading indicator indexes for various countries show a two-point gain in January for the U.K. to 123 (1970 = 100). This is the first advance for the U.K. index in 13 months. The Conference Board adds, "A substantial majority of the components rose, and scattered early figures for February suggest this upward trend has continued."

The Conference Board cautions that the U.K. turnaround is still tentative. The U.K. indicator has yet to give even one of the three major signals used by the Conference Board to confirm full-fledged recovery.

However, recovery could be real in the U.K. Certainly, the London stock market is bullish. The Financial Times Index, corresponding to the Dow-Jones Industrials average in the U.S., has risen sharply to an all-time peak. Since the stock market is supposed to discount (reflect) future earnings, the profits picture in the U.K. would seem to be much improved after a very dark past year. □

OTA report, more interferon news released

The increasingly orchestrated interest in genetic engineering achievements was kept at a high pitch last week with two separate events: the official release of a major report on genetic engineering from the Congressional Office of Technology Assessment and the announcement that the protein interferon has been made in yet another microorganism.

Researchers from Cetus Corp., based in Berkeley, Calif., say that they've produced the antiviral and potentially anticancer protein interferon in the bacterium *Bacillus subtilis* by means of recombinant DNA techniques. The research effort was led by Shing Chang, and was described at the Biology of the Interferon System Meeting, held in Rotterdam, the Netherlands. The Cetus announcement follows closely success of Genentech, South San Francisco, Calif., in producing interferon in yeast (C&EN, March 9, page 6).

C&EN staff photo

Farley:* B. subtilis *has advantages

Such efforts signal a growing interest in exploiting organisms other than *Escherichia coli*, the bacterium that until recently has been the choice for most genetic engineering feats (C&EN, April 6, page 17). "This is the first time a human protein has been produced in the bacteria," Cetus president Peter J. Farley says of *B. subtilis*. He adds that this bacterium has advantages over *E. coli* for industrial uses. "It has better fermentation characteristics," he says, "and it might be safer because it is not naturally associated with mammals." *B. subtilis* is a ubiquitous microorganism, found commonly in soil, whereas *E. coli* inhabits the intestine. *B. subtilis* also tends to secrete many of the proteins it makes, unlike *E. coli*. However, Farley says, so far the

Makers of major pigments await turnaround

Production of carbon black and titanium dioxide is expected to rise modestly, if at all, this year following big 1980 decline

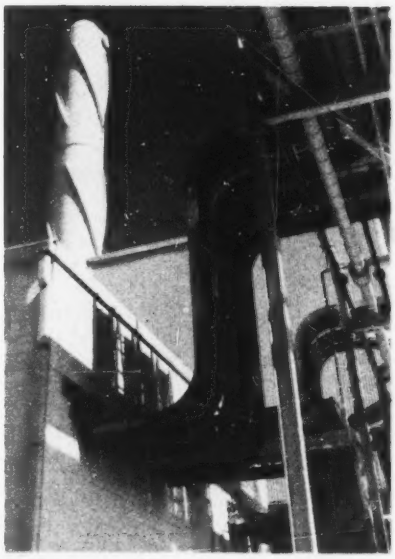
For the two leading U.S. pigments—carbon black and titanium dioxide—1981 started in the economic doldrums and may wind up that way after a shocking decline in 1980. Full recovery may wait for 1982 for titanium dioxide and even later for carbon black.

Of the two, carbon black production had the larger drop in 1980, more than 20% from 1979. Titanium dioxide production fell about 7%. Output of neither pigment will match that of 1979 for some time, certainly not in 1981.

Both pigments are mature products, with recent growth rates running below growth in real-dollar gross national product. The outlook remains low growth. Carbon black may take until the mid-1980's to get back to 1970's volume levels and to financial health. Titanium dioxide might do better, especially if export sales move up as foreign production slows because of plant closings.

Despite the grim current production picture for carbon black and titanium dioxide, these pigments remain businesses of large size and value. In 1981, combined production of the two is expected to be about 4.1 billion lb, with carbon black's output more than twice that of titanium dioxide. At current selling prices, the two should split an annual dollar value of about $1.8 billion. By the end of the year, inflation could drive this value to $2 billion or more.

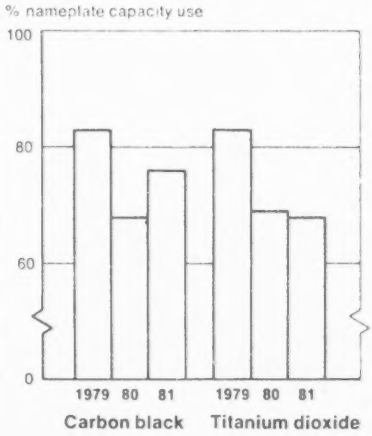
Both pigments are vital to their main end products and have no major competition. Carbon black has no peer as a material imparting both color and longer life—abrasion resistance—to rubber fabricated as tires and other products. Similarly, titanium dioxide is by far the most economical material to provide whiteness, opacity, and reflectivity to paint, paper, and other products.



Finishing section of Du Pont's titanium dioxide plant at De Lisle, Miss.

Both pigments face a continuing crimp in their main markets for the obvious reason, rising prices. Carbon black's major consumers, the tire companies, have long looked for ways to reduce the carbon black content of tires to hold down tire price increases. So far, their success has been limited, but a reduction in the carbon black fraction of total tire weight is possible by mid-decade. For now, the reduction in tire size and the increase in tire life are much more important than lower carbon black content as a contributor to the decline in overall carbon black consumption.

Capacity use for pigments remains low in 1981



Sources: Commerce Department, industry, and C&EN estimates

Similarly, titanium dioxide's reduction in share of end product weight has resumed in its largest use, paint. Lower use of the pigment in paint, especially in house paint, was initiated in the mid-1970's as a way to hold down or lower selling prices for paint. The result, then and more recently, was that some consumers turned away from paint because of lower quality and switched to alternative wall coverings. The trend may continue, leading to a lower share of paint in the titanium dioxide market later in the 1980's.

In contrast to carbon black, titanium dioxide has one big potential plus in its future—exports. Exports are expected to continue growing as a result of surplus U.S. plant capacity and shrinking foreign capacity. The latter factor also could lead to a decline in titanium dioxide imports into the U.S. as well.

The real problem that titanium dioxide may face in two to four years is a worldwide supply crunch. For 1981, worldwide capacity may decline if more capacity is shut down outside the U.S. than is added here through debottlenecking. No large new titanium dioxide plant has been announced anywhere that could be in operation within three years.

Relatively rapid growth in U.S. exports of titanium dioxide could combine with growth in U.S. demand to use up spare capacity. Although U.S. nameplate capacity is an estimated 1 million tons per year, actual production would have difficulty topping 850,000 tons, the practical maximum.

Exports could become a newly profitable side of this relatively unprofitable business, leading to increases in U.S. prices as well. If such a development occurs by the mid-1980's, the titanium dioxide business could become more financially interesting than it is now.

For details on the immediate market outlook for these pigments, see the following pages.

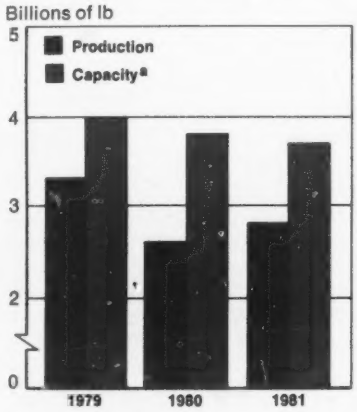
Bruce Greek, Houston

C

Carbon black

- ***Demand rising a bit***
- ***Capacity declining***
- ***Prices rising***

PRODUCTION/CAPACITY



a As of first quarter.

HOW MADE

Partial oxidation of residual hydrocarbons from oil refining

MAJOR END USES

Tires 65%, other rubber products 25%, colorant and filler for plastics, inks, etc., 10%

FOREIGN TRADE

Exports—to decline about 20% to about 130 million lb in 1981; imports—small, about 25 million lb in 1981

PRICES

25 to 41 cents per lb with most between 32 and 38 cents

COMMERCIAL VALUE

$900 million for total production, 1981

U.S. producers of carbon black are not the most optimistic people. Some, in fact, would welcome stagnation in the business as an improvement. They may get their wish in 1981, since carbon black production apparently is only slightly lagging that of 1980.

Production and capacity figures etch the essential problems faced by carbon black producers. In 1980, production totaled about 2.6 billion lb, down more than 20% from 1979. These estimates are for the dominant furnace-process types of carbon black. About 100 million lb of thermal-process types also was produced in 1980, easing the decline rate just slightly.

During the same time, plant capacity fell as producers shut down at certain sites. And capacity continues to fall. Roughly 200 million lb per year of capacity was closed permanently in 1979, and nearly 100 million lb in 1980. That brought capacity to about 3.7 billion lb at the beginning of 1981. Since the beginning of the year, other plant closings have been scheduled or carried out.

Carbon black's troubles aren't new. Both production and capacity peaked in 1973 and 1974. Production had reached about 3.5 billion lb, and capacity 4.2 billion lb.

Carbon black's decline over most of the past decade comes directly from its nearly one-product use pattern. In the U.S., some 90% of it goes into compounded rubbers used mainly in autos and other vehicles. Vehicle demand growth has limped along slower than growth in real-dollar gross national product. Higher cost of gasoline and diesel fuels has led to smaller, lighter cars equipped with radial tires. This combination can mean only lower demand for carbon black.

Tire markets, including retreading, make up about two thirds of U.S. carbon black consumption. This share has begun to decline very slowly because of the flattening in tire demand and because of growth in carbon black use in plastics and other areas.

The tire problem is one of both volume and product life. A shift to smaller tires, including smaller spare tires, for smaller cars has begun a trend that is forecast to reduce tire weight a third. The amount of carbon black used will decline by the same amount.

The product life problem is similar but more complex. Radial passenger tires are proving to go more miles than expected, with the anticipated life cycle apparently still rising. Some industry analysts report comments from auto dealers that more and more cars are being traded in with their original tires still on. Then, too, the average number of miles driven per car is declining, further stretching out the life cycle of tires and reducing demand for carbon black.

These factors in the tire business underlie the current dull outlook for carbon black. Certainly, it will be at least through 1982 before demand can get back above the 3.3 billion lb produced in 1979. Some industry analysts look for a much longer lag before production again matches 1979 volume. They expect a five-year wait before the 20%+ decline in 1980 will be recovered.

Recovery time could be even longer, or perhaps never, if efforts succeed to reduce the amount of carbon black in tire rubber, reversing a rising trend of more than 10 years. Costs, of course, are behind this attempt. Carbon black prices have soared as producers passed through the rapidly increasing cost of their feedstocks, mostly a special oil refinery fraction called carbon black oil. Recent price increases have held up in contrast to some hikes from 1975 to 1980, when producers were unable to recover the increases in feedstock costs. This failure led to plant shutdowns.

A decline in use of carbon black in tires plus longer tire life undoubtedly will bring more plant shutdowns, perhaps some this year. This suggests that producers don't seem worried about a capacity shortfall, even with an overall 10% decrease in year-end capacity over the three years through 1981.

Exports of carbon black will not help the outlook either. During 1981, exports are forecast to decline about 20% from 1980 exports of about 160 million lb. Major importers of U.S.-produced carbon black are the industrialized countries of the Far East and Europe with small quantities going to many other countries as well.

Perhaps lower plant capacity will bring eventual profit improvement to beleaguered carbon black producers. But this is not expected anytime soon, not in 1981.

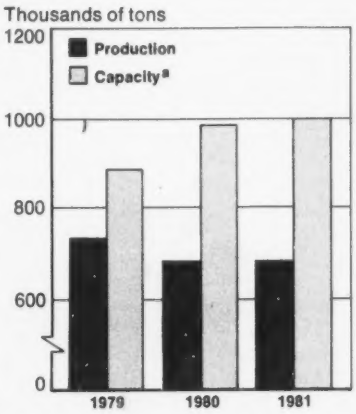
Key Chemicals

Titanium dioxide

TiO_2

- ***Demand to recover***
- ***Capacity flat***
- ***Prices firmer***

PRODUCTION/CAPACITY



a As of first quarter.

HOW MADE

Recovered from natural or synthetic ores using chlorine or sulfuric acid

MAJOR END USES

Surface coatings 50%, paper coatings and fillers 25%, plastic and rubber fillers 15%, ceramics 5%

FOREIGN TRADE

Exports—rising to more than 55,000 tons in 1981; imports—rising to more than 100,000 tons in 1981

PRICES

Anatase form 64 cents per lb, bulk contract; rutile form 69 cents per lb, bulk contract

COMMERCIAL VALUE

$900 million for total production, 1981

U.S. producers of titanium dioxide suffered in 1980 about as badly as did producers of most other chemicals. They now face a year of meager, if any, production gains. It possibly will take until 1982 to recover to the prerecession level of 1979.

In the absence of final government data, best industry guesses are that 1980 titanium dioxide production decreased about 7% from 1979. Producers agree on 1979 production at 730,000 tons and for 1980 at about 680,000 tons. For 1981, production is expected to be about equal to 1980 or up a small amount, 10,000 tons or so.

Hence, production continues to be limited by demand, not plant capacity. Currently, nameplate capacity is about 1 million tons a year. Small additions through process improvements and other debottlenecking will add a small amount of capacity in 1981. But nothing is in store like Du Pont's big new plant at De Lisle, Miss., completed at about the end of 1979.

On the basis simply of comparing production and capacity, the U.S. titanium dioxide industry operated slightly under 70% of nameplate capacity in 1980 and will run at about the same rate in 1981. Some plants were run at higher rates and others at low rates or not at all while shut down for process modifications. Even so, and with a normal top operating rate of about 85% of nameplate capacity, current capacity use is low enough to hurt this industry, which has a high capital investment per unit of product as well as high energy costs.

Quarter to quarter, the outlook for production this year is much like many parts of the chemical industry. The first quarter compared unfavorably with the good first quarter of 1980. The second quarter should be about even with last year's recessionary second quarter, when sales and production declines began. Then the second half, particularly the fourth quarter, is expected to be ahead of 1980 as part of the general improvement in the economy. By early 1982, titanium dioxide production likely will match or exceed 1979's rate.

The falloff in demand for titanium dioxide in 1980 came at the hands of two slumping markets hurting many other chemicals—housing and autos. Because about half of U.S. titanium dioxide use is in various surface coatings, housing and autos obviously have a lot to do with total consumption.

Ordinarily in a slump in these durables markets, the paint business is supposed to perk up a bit—partly because laid-off workers have time to work on their homes. Unfortunately, the retail part of paint sales, called trade sales, has fallen off in spite of an upsurge in layoffs. The problem comes from the paint industry's efforts to hold down costs by lowering quality, among other things by reducing titanium dioxide content of paints. The public has noticed and switched to metal or plastic siding and paper and plastic wall coverings. The result has been a decline in use of titanium dioxide in trade sales.

Industrial paints do better. Quality demand has kept up the pigment level. Current volume increases in this area are expected to cause a small increase in titanium dioxide consumption.

Prospects for titanium dioxide in paper coatings and fillers and in a host of small uses indicate little or no growth. In spite of increased demand for printing and other papers, growth in this use will remain less than real-dollar growth in gross national product.

Use of titanium dioxide in plastics, which fell more in 1980 than in other uses, likely will recover correspondingly faster now and have higher future growth rates. Plastics additive use is expected to grow slightly faster than plastics themselves, which will continue to benefit from relatively lower energy costs compared with other materials. However, the share of total use of titanium dioxide going into plastics is small and can't be expected to have much effect on the whole.

After a small decline in exports of titanium dioxide in 1980, exports are expected to rise in 1981 to about 55,000 tons from exports estimated for 1980 of under 45,000 tons. As is the case for carbon black, titanium dioxide exports go to a diverse group of countries. Again, as might be expected, exports of titanium dioxide go in larger quantities to industrialized countries of Europe and the Far East. Western Hemisphere countries also import sizable quantities of titanium dioxide from the U.S., with Canada, Venezuela, and Brazil among the leaders.

NOTE

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May 4, 1981

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Financing needs still press chemical firms

1980 recession didn't shore up company balance sheets as much as previous recessions; cash fell, debt rose, and key ratios barely gained

William F. Fallwell
C&EN, New York

The traditional reaction of a chemical company in its short-term cash management in a year like 1980 would be a sudden conservative swing. After letting out the financial sails in the previous expansion—with big increases in inventories, receivables, and short-term debt—the company would tack carefully into the wind. Control would be the order of the day for inventories, receivables, and debt. And the company's cash coverage of liabilities would begin to swing upward.

Some of this did happen in 1980, but not nearly so much as in the previous recession in 1975. The result is that companies are running not much tighter financially than before the recession (C&EN, May 5, 1980, page 10). "Liquidity" (cash and relative cash coverage of liabilities) hasn't changed much.

A C&EN survey of 20 leading U.S. basic chemical companies' 1980 annual reports shows the extent of the industry's continuing financial pinch:

- Overall, companies' cash fell 11% in 1980; it rose 12% in 1975.
- "Current ratio" (current assets divided by current liabilities) eked out a slight gain, to an average 2.0 from 1.9 in 1979; in 1975, the rise was to 2.4 from 2.2 in 1974.
- Coverage of current liabilities with actual cash (the "cash ratio") similarly edged up to an average of 0.20 from 0.19 in 1979; in 1975, this ratio rose to 0.33 from 0.28 in 1974.

Nine companies, many of them smaller ones, did lift their store of cash, including short-term investments convertible into cash, in 1980. Along with other measures described below, this created much stronger balance sheets, notably at Allied, American Cyanamid, Celanese, Reichhold Chemicals, and Rohm & Haas.

But the cash drain at the majority of companies pulled the combined total down 11% from 1979. The store of cash dropped at the largest companies—21% at W. R. Grace, 22% at Monsanto, 41% at Du Pont, 33% at Dow Chemical, and 46% at Union Carbide.

Partly as a result, overall current ratios hardly budged in 1980 from a year before. Ten companies managed a gain, led by Rohm & Haas' rise from 2.3 to 2.7, the highest of the group. But at several of the industry giants,

Financial ratios barely rose in 1980, and cash declined

	1980 (recession)			1979			1975 (recession)			1974		
	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio
Air Products	$ 64.5	1.3	0.18	$ 47.0	1.4	0.15	$ 37.2	1.3	0.19	$ 45.8	1.4	0.28
Akzona	17.7	2.1	0.09	18.5	2.2	0.10	12.2	2.6	0.12	9.0	3.2	0.11
Allied	189.0	1.4	0.16	126.0	1.2	0.09	86.0	2.2	0.27	72.8	2.0	0.22
American Cyanamid	180.6	1.8	0.23	146.2	1.6	0.18	154.1	2.4	0.46	179.4	2.4	0.54
Cabot	108.2	2.0	0.34	19.3	2.0	0.08	23.4	3.0	0.34	25.2	2.4	0.28
Celanese	274.0	2.0	0.47	214.0	1.8	0.36	146.0	1.7	0.36	117.0	1.7	0.31
Diamond Shamrock	28.4	2.2	0.07	31.3	1.9	0.08	52.7	2.1	0.28	35.5	1.4	0.16
Dow Chemical	168.0	1.6	0.06	252.0	1.4	0.10	374.9	1.5	0.25	423.3	1.4	0.27
Du Pont	219.0	2.3	0.11	370.0	2.6	0.21	139.2	2.0	0.11	128.0	2.6	0.13
Ethyl Corp.	108.9	2.5	0.53	119.0	2.8	0.62	103.9	3.5	0.99	42.5	2.6	0.33
W. R. Grace	124.9	1.5	0.11	157.2	1.6	0.15	110.1	1.8	0.16	168.2	1.6	0.20
Hercules	36.7	2.0	0.09	56.3	1.9	0.14	28.4	2.0	0.12	22.2	2.0	0.08
Monsanto	210.6	2.1	0.18	271.3	2.2	0.24	425.6	3.4	0.88	324.1	2.9	0.63
Olin	12.9	1.8	0.04	25.6	1.8	0.08	98.2	2.4	0.44	98.2	2.3	0.46
Pennwalt	9.1	2.1	0.04	17.9	2.2	0.09	21.9	3.1	0.22	2.2	2.0	0.01
Reichhold Chemicals	12.2	2.2	0.12	10.2	2.1	0.09	5.6	2.2	0.11	22.8	2.3	0.45
Rohm & Haas	85.3	2.7	0.33	69.6	2.3	0.25	17.5	2.4	0.09	19.7	2.3	0.10
Stauffer Chemical	86.0	1.8	0.17	55.9	1.7	0.14	53.0	3.1	0.42	53.6	2.5	0.39
Union Carbide	243.0	2.2	0.14	449.0	2.2	0.26	585.1	2.5	0.55	426.1	2.2	0.38
Witco Chemical	74.3	2.2	0.45	72.6	2.0	0.41	14.5	2.4	0.25	14.6	1.9	0.18
TOTAL (average for ratios)	**$2253.3**	**2.0**	**0.20**	**$2528.9**	**1.9**	**0.19**	**$2489.5**	**2.4**	**0.33**	**$2230.2**	**2.2**	**0.28**
ANNUAL CHANGE	**−11%**			**0%**			**12%**			**−17%**		

Note: Current ratio is current assets divided by current liabilities. Cash ratio is cash and marketable securities divided by current liabilities.

Debt still rose as inventories, receivables climbed

$ Millions	1980 FISCAL YEAR END Inventories	% change from 1980	% change from 1979	Receivables	% change from 1980	% change from 1979	Payables[a]	% change from 1980	% change from 1979	Short-term debt	% change from 1980	% change from 1979
Air Products	$ 114.6	14%	6%	$ 298.8	17%	27%	$ 182.5	25%	11%	$ 34.2	−1%	−13%
Akzona	121.0	2	28	166.3	0	22	109.7	−1	26	81.1	33	75
Allied	601.0	0	81	785.0	4	52	673.0	−12	93	33.0	−82	1942
American Cyanamid	495.3	−4	3	731.6	6	21	282.7	6	b	89.6	−55	43
Cabot	294.7	12	30	231.3	19	46	200.6	16	54	51.2	36	52
Celanese	393.0	12	11	518.0	7	21	237.0	0	35	49.0	−25	51
Diamond Shamrock	387.7	23	32	484.6	9	39	263.6	14	46	21.1	−41	−31
Dow Chemical	1,934.0	47	31	2,159.0	5	25	1183.0	1	40	736.0	22	30
Du Pont	2,010.0	1	17	2,110.0	8	21	830.0	7	35	393.0	71	−11
Ethyl Corp.	144.2	−11	20	244.9	−2	22	79.8	−1	b	18.9	−1	2
W. R. Grace	812.5	6	8	743.5	1	16	501.3	12	23	228.1	−14	12
Hercules	337.2	5	1	417.8	2	23	153.3	−8	b	148.3	72	71
Monsanto	832.3	−9	26	1,334.1	4	15	425.8	−27	b	238.8	2	b
Olin	286.8	10	−1	291.0	0	13	147.8	10	−4	70.6	13	−19
Pennwalt	205.7	8	12	218.4	3	22	70.7	5	28	73.5	21	38
Reichhold Chemicals	74.7	−8	0	132.9	3	19	69.3	−9	19	16.1	11	−23
Rohm & Haas	318.9	13	20	272.1	−2	15	120.3	−1	41	32.6	−16	−14
Stauffer Chemical	305.2	−4	15	361.8	17	18	140.7	20	20	275.6	34	38
Union Carbide	1,887.0	6	15	1,598.0	12	14	432.0	−18	22	317.0	52	−47
Witco Chemical	83.5	−25	28	191.6	23	41	154.1	−4	65	6.6	−17	65
TOTAL	$11,639.3	7%	19%	$13,290.7	7%	22%	$6257.2	−4%	b	$2914.5	10%	b

a Generally trade accounts; other major liabilities included for Akzona, Cabot, and Witco. b Accounting change makes comparison impossible.

the ratio fell—to 2.3 from 2.6 at Du Pont, to 2.1 from 2.2 at Monsanto, and to 1.5 from 1.6 at Grace.

Cash ratios continue to show a sharp drop from levels of a few years ago. With the scant gain in 1980 to 0.20 from 0.19 in 1979, the 20 companies' average is way below where it wound up in the previous recession. Here, there is a much greater difference among companies than in the current ratio. Nine pushed the cash ratio up in 1980, some of them to much higher levels than the industry average—to 0.34 from 0.08 at Cabot, to 0.47 from 0.36 at Celanese, to 0.33 from 0.25 at Rohm & Haas, and to 0.45 from 0.41 at Witco Chemical. The industry's other outstanding cash-rich company is Ethyl, although the company's ratio fell to 0.53 in 1980 from 0.62 in 1979.

At the opposite end of the scale, the cash ratio fell to 0.11 from 0.21 at Du Pont, to 0.09 from 0.14 at Hercules, to 0.07 from 0.08 at Diamond Shamrock, to 0.06 from 0.10 at Dow Chemical, to 0.04 from 0.08 at Olin, and to 0.04 from 0.09 at Pennwalt.

Hence, if a business recovery is under way, the chemical industry is starting it with less financial leeway than at the start of the previous expansion in 1976. Companies may be learning to live with less coverage of their liabilities in times of high inflation, but the stern measures some companies took in 1980 show that such acquiescence is not universally accepted.

Behind the overall financial ratios, a look at the biggest day-to-day financing needs of these companies shows how widespread the pressure remained in 1980. Despite the recessionary drop in business volume, inventories (in dollars) still rose 7% in 1980 from 1979. A consolation is that this rate was down from 19% in 1979, in fact to below the inflation rate in chemical prices. Six companies actually cut inventories.

A similar picture emerges for the industry's receivables (uncollected bills to customers). After a 22% rise in 1979, receivables' pace slowed to a 7% gain in 1980. Two companies, Ethyl and Rohm & Haas, each pruned receivables 2%.

Even with the slower rates, receivables and inventories created an additional $1.7 billion financing load for the 20 firms after $4.1 billion in 1979.

Companies only added to this load by tightening up in paying their own bills. After stretching out payables about a third in 1979 (on a different accounting basis at some companies), companies pulled down their outstanding bills 4% in 1980. Of course, doing so ate up more money, $255 million for the group.

With about $2 billion in extra financing created by inventories, receivables, and payables in 1980, it isn't surprising that companies increased their short-term debt 10% for the 20 firms, or $266 million. In 1979, the debt increased about 16% (with a few differences in accounting).

Despite the overall standoff in companies' short-term financial management in 1980, some firms carried on the cinching-up tradition in a business downtrend. For example, under its new management, Allied turned decidedly conservative. The company increased its cash 50% to $189 million, raised its current ratio to 1.4 from 1.2 in 1979, picked up its cash ratio to 0.16 from 0.09, held inventories to no gain and receivables to just a 4% gain, trimmed payables 12%, and chopped its short-term debt (incurred largely for an acquisition a year ago) 82%.

Among smaller companies, 1980 was notably conservative at Witco Chemical. The company raised its relatively large cash position 2% from 1979 to $74.3 million, its current ratio to 2.2 from 2.0, and its cash ratio to a very high 0.45 from 0.41. At the same time, Witco knocked down inventories 25%, cut payables 4%, and reduced short-term debt 17%. Only in receivables did Witco allow much of an increase, 23%. □

Research funds to be cut back at EPA

Major cuts proposed for work on energy-related pollution problems, outside research; small increases asked for hazardous waste projects

The Office of Research & Development at the Environmental Protection Agency is a major part of the agency's operations, with funding of $303 million planned for fiscal 1982—22% of EPA's total budget. Still, after healthy increases in R&D funding in previous years, the 1982 funding levels are down 12% from the year before.

Major cuts in support are proposed for studies on energy-related pollution problems, and EPA's extramural research efforts are being trimmed sharply. Small proposed increases will go to research on groundwater and the health effects of toxic substances.

The purposes for EPA's research efforts vary. Acting assistant administrator for R&D Richard M. Dowd explains that the foremost purpose is to "carry out research on topics in which new knowledge is needed by the agency or in which earlier results need checking." Another function is evaluation of new scientific areas for EPA. And EPA research serves as a source of scientific and engineering expertise that the agency can use to solve specialized problems, such as those arising from the nuclear power plant accident at Three Mile Island. It also serves as a quality check on programs of other EPA offices.

Much of EPA's R&D is performed in the agency's own laboratories, but in 1982 about 63% of the work will be handled outside the agency through contracts or grants. In fact, the competitive grants program has been growing. "In 1981 about $25 million went to our competitive grants program," Dowd says, "but we don't have any decision yet on how much it can get for 1982."

This extramural research effort could suffer the most budget cuts. Dowd says it is simply a matter of people and money. The Office of Management & Budget told EPA it would have to cut back its staff size, as will most other agencies, and EPA has tried to do this. But when the research budget was cut, most cuts were made from extramural work, since only a limited amount could be trimmed from in-house research before more EPA staff members would have to be released.

Some highlights of the proposed budget reveal EPA's changing goals. For instance, in the areas of air quality, EPA is phasing out its diesel exhaust health effects studies on the assumption that the necessary data will be available by the end of this year. The agency also is reducing its involvement in large-scale epidemiological studies of the effects of air pollutants, relying on other federal agencies for the needed data. One small increase in this field will be for testing the health effects of carbon monoxide exposure. The net decrease in funds for air quality research will be about $3 million.

Water quality R&D will be cut about $14.9 million, much of which will stem from the termination of the Chesapeake Bay and Great Lakes programs and the Clean Lakes program. Other reductions will be in developing methods for measuring inorganic chemicals in water, in control of pollution from storm drain runoff, and in studies on water reuse and conservation.

The research budget for drinking water studies, however, will rise for 1982—mostly because of an increase in interest in the problems of groundwater contamination. Most of the increase will go toward trying to determine how organic contaminants move through groundwater, as well as their fate, and toward finding improved methods for monitoring groundwater.

An increase has been proposed for the Office of Toxic Substances Research, too. A good deal of the $2.5 million rise will be for studies relating to neurotoxicity, genetic toxicology, and reproductive teratology. Solid-waste studies are getting a small increase, despite the completion of monitoring work at the Love Canal dump site. Increases in the area will be for developing new monitoring methods and ways to assess environmental damage caused by improper disposal of hazardous wastes.

Scattered gains and losses mark R&D programs at EPA

$ Millions	1980[a]	1981[b]	1982[b]	% change 1981-82
Energy	$103.4	$104.9	$70.1	−33%
Air quality	64.4	67.5	64.4	−4.6
Water quality	67.3	62.9	48.0	−24
Toxic substances	30.9	35.5	38.0	7.0
Hazardous waste	13.1	29.6	31.0	4.7
Drinking water	23.0	26.3	29.7	13
Pesticides	12.9	10.6	6.9	−35
Interdisciplinary	7.7	6.4	6.5	1.6
Radiation	2.9	3.2	3.0	−6.2
Other	18.3	16.1	5.4	−66
TOTAL	$345	$363	$303	−16%

a Actual. b Obligations as proposed in current Administration. **Source:** Environmental Protection Agency

The biggest bite out of EPA's R&D funding is set to come from its energy-related research. The $34.8 million decrease is to be split about evenly between environmental effects studies and engineering technology programs. Major areas being phased out include research on utility ashes and scrubber sludges, work on indoor pollution and the effects of residential burning of wood, research on hazardous pollutants from new energy sources, and studies of environmental effects of offshore exploration for gas and oil. One program that will be fully funded, Dowd says, is the agency's research on acid rain.

The reduction of EPA's research budget is, of course, part of the new austerity urged by the President. The specific cuts often seem to have the mark of the Administration on them, and may not have been the first choice had EPA been able to make all the decisions. The cutbacks in research on pollutants from energy sources could be seen as a way to speed development of synthetic fuels plants, and cuts in water quality work may ease some worries of manufacturers. While EPA did have some opportunity to appeal the budget reductions suggested by OMB, it appears that many cuts were made with attention to the Administration's goals of easing the regulatory burden to encourage industry to invest more capital and raise productivity. □

C&EN's Top 50 Chemical Products & Producers

Weak demand in such key outlets as automobiles, housing, and appliances, coupled with an easing in some major overseas markets, undercut chemical operations in the U.S. last year. The result shows up clearly in the following pages of C&EN's annual Top 50 compilation of the industrial chemicals produced in greatest volume in the U.S. and the U.S. companies with the largest dollar volume of worldwide chemical sales.

Total pounds of output of the Top 50 chemicals declined—almost 4%—for only the second time since C&EN began ranking these products in 1969. Organic chemicals among the Top 50 products were especially hard hit, collectively declining about 8% in production volume.

All in all, only 10 of the 50 big-volume chemicals managed to rack up a higher poundage last year, with eight of these being inorganic chemicals. And the increases generally were moderate at best, with only two higher than 10%. For the organic products, lower output reflects to a large extent lower production for practically all the major plastics, synthetic fibers, and synthetic rubbers; the inorganics were buoyed by good demand, both in the U.S. and overseas, for fertilizer chemicals.

On the other hand, worldwide sales of chemicals increased for all but a handful of the Top 50 U.S. producers. For the group as a whole, dollar volume of chemicals hit $100 billion as price increases averaging about 20% above the year before more than compensated for reduced output. But the 11% increase in sales was less than half what the 50 firms had rung up the year before. Companies with a big stake in fertilizers turned in a particularly strong performance, thanks both to improved prices and strong markets.

Last year, all of the companies ranked among the Top 50 had chemical sales of more than $600 million, and nearly three quarters of them moved more than $1 billion worth of chemicals into the marketplace. Du Pont, meanwhile, became the first U.S. company to ring up more than $10 billion in chemical volume.

This year sales undoubtedly will rise again. Higher selling prices will again get much of the credit. Even though worldwide demand for chemicals remains sluggish, U.S. production is not likely to slump any time this year as it did during the first half of 1980. Consequently, although growth will be less than spectacular—and may, in fact, not even carry production back to 1979 levels—it's a safe bet that the year's totals will be higher than those of 1980.

Output of big-volume chemicals fell in 1980

William J. Storck
C&EN, New York

There was nothing to cheer about in terms of volume output in the U.S. chemical industry last year. Yes, sales of U.S. chemical companies increased. Yes, earnings were up moderately. But physical volume of the basic chemicals and the downstream polymers is another story. They both fell. In fact, if it hadn't been for inflation, exports, and some tightening of operations, things might have been much worse on the financial front as well.

The drop in output last year ended a half-decade climb for production of basic chemicals in the U.S. The last time that total production fell for the 50 largest-volume chemicals was in 1975 when output dropped 9.0%. Last year producers were somewhat luckier, if you can call any drop lucky—as output fell just 3.6%.

Largely preliminary figures show that production of the 50 largest-volume chemicals last year was 543 billion lb, compared with a revised 563 billion lb produced in 1979. It is important to keep in mind that the 1980 results are largely preliminary and probably will change when final figures eventually are published by the government. When C&EN's list was published in 1980, the preliminary figures showed that production had risen 7.6% to 565 billion lb from 1978 figures. However, when revised production figures were published by the government, output in 1979 came to 563 billion lb, a 7.2% increase over the year before.

C&EN's Top 50 Chemical Products

Just as last year, the change in production was led by the organic chemicals. While production of the Top 50 chemical products was falling 3.6% in 1980, production of organics on the list fell 8.2% to 174 billion lb from 1979. Inorganic chemicals production dropped just 1.3% to 369 billion lb.

There had been indications almost all year that chemical production would fall in 1980. The main one was the Index of Industrial Production published by the Federal Reserve Board. The average seasonally adjusted index for the broad category chemicals and allied products was 206.7 (1967 = 100) for 1980, a 1.8% drop from 1979. For basic chemical production, the seasonally adjusted

About the Top 50 list of chemical products

Government data, trade association figures, industry estimates. All of these go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking or incomplete.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back for many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1980. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, production figures for 1979 that appear in the table on page 37 may be different from those published at this time last year. The final reports also can affect the rankings of chemicals. The 1979 rankings of 13 of the chemicals listed in the table on page 37, for example, are different from those in the similar table published by C&EN a year ago.

The list itself covers production figures for the U.S., and includes chemicals produced for export. Candidates for the list include all basic, intermediate, chemically homogeneous finished products. These range from chemical building blocks such as ethylene and propylene to finished products such as vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, potash, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead-burned) dolomite is excluded in the calculations of lime production.

In the organics, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily, because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included. Admittedly, this makes the list less pure chemically. Mixed xylenes are on the list. So is the para isomer of xylene. If production volume had warranted, the ortho isomer also would be included.

Production figures are published by the government and trade associations in a variety of units—millions of pounds, thousands of tons, billions of cubic feet, millions of gallons, metric tons. To provide an accurate ranking and to make comparison of production volumes easier, C&EN not only gives production in common units but converts production to billions of pounds.

The Top 50 list, in addition to listing production figures for the past two years, indicates growth rates for the past year, the previous year, the past five years, and the past 10 years, giving the reader a historical perspective on growth for each chemical.

Organic chemicals led Top 50 to 3.6% production decline in 1980

Rank 1980	Rank 1979[a]		Production: Billions of lb 1980	Billions of lb 1979	Common units[b] 1980	Common units[b] 1979	Average annual change 1979–80	1978–79	1975–80	1970–80
1	1	Sulfuric acid	80.69	83.98	40,343 tt	41,988 tt	−3.9%	2.2%	4.5%	3.2%
2	3	Ammonia	37.98	36.24	18,988 tt	18,121 tt	4.8	5.4	3.0	3.2
3	2	Lime[c]	35.36	38.78	17,681 tt	19,392 tt	−8.8	—	−0.5	−0.8
4	4	Oxygen	34.35	35.35	415 bcf	427 bcf	−2.8	−0.2	3.3	3.9
5	5	Nitrogen	34.20	29.93	472 bcf	413 bcf	14.3	5.4	13.3	12.1
6	6	Ethylene	27.54	29.90	27,544 mp	29,904 mp	−7.9	15.2	6.1	4.2
7	7	Sodium hydroxide	22.62	24.78	11,310 tt	12,392 tt	−8.7	15.7	3.4	1.1
8	8	Chlorine	22.38	24.22	11,190 tt	12,108 tt	−7.6	9.6	4.2	1.4
9	9	Phosphoric acid	21.71	20.27	10,857 tt	10,135 tt	7.1	8.3	7.2	6.7
10	12	Ammonium nitrate[d]	17.17	15.60	8,586 tt	7,800 tt	10.1	8.2	3.9	2.9
11	10	Nitric acid	17.09	17.13	8,544 tt	8,564 tt	−0.2	7.9	2.6	1.2
12	11	Sodium carbonate[e]	16.55	16.51	8,275 tt	8,253 tt	0.3	−0.4	3.0	1.6
13	14	Urea[f]	14.34	13.53	14,335 mp	13,534 mp	5.9	24.3	15.3	8.2
14	13	Propylene	13.71	14.20	13,711 mp	14,198 mp	−3.4	9.1	9.5	7.5
15	16	Toluene[g]	11.27	11.86	1,555 mg	1,636 mg	−5.0	55.2	17.1	6.5
16	15	Benzene	10.98	12.29	1,495 mg	1,672 mg	−10.6	12.4	7.8	2.8
17	17	Ethylene dichloride	9.97	11.79	9,974 mp	11,794 mp	−15.4	7.2	4.6	2.9
18	18	Ethylbenzene	7.61	8.45	7,609 mp	8,448 mp	−9.9	0.8	9.5	4.7
19	21	Carbon dioxide[h]	7.09	7.07	3,543 tt	3,533 tt	0.3	11.1	13.9	12.1
20	20	Methanol	7.00	7.37	7,002 mp	7,367 mp	−5.0	14.3	6.2	3.6
21	19	Styrene	6.90	7.48	6,897 mp	7,484 mp	−7.8	4.1	8.1	4.8
22	23	Vinyl chloride	6.46	6.39	6,458 mp	6,388 mp	1.1	−8.0	9.0	4.8
23	22	Xylene[g]	6.40	6.89	883 mg	950 mg	−7.1	12.4	6.7	5.1
24	24	Terephthalic acid[i]	5.92	6.16	5,924 mp	6,159 mg	−3.8	3.4	5.3	11.9
25	25	Formaldehyde[j]	5.77	5.97	5,768 mp	5,971 mp	−3.4	−6.4	4.8	2.7
26	26	Hydrochloric acid	5.50	5.95	2,750 tt	2,973 tt	−7.5	6.6	6.5	3.2
27	27	Ethylene oxide	4.95	5.67	4,951 mp	5,665 mp	−12.6	13.0	2.1	2.6
28	28	Ethylene glycol	4.24	4.73	4,243 mp	4,729 mp	−10.3	21.2	2.2	3.4
29	30	Ammonium sulfate	3.92	3.94	1,958 tt	1,971 tt	−0.7	1.4	−1.5	0.3
30	29	*p*-Xylene	3.83	4.65	3,829 mp	4,650 mp	−17.7	32.3	9.1	9.2
31	31	Cumene	3.16	3.92	3,161 mp	3,917 mp	−19.3	15.9	9.5	4.8
32	32	Butadiene[k]	2.89	3.58	2,894 mp	3,583 mp	−19.2	1.9	2.2	−0.7
33	34	Acetic acid	2.82	3.27	2,817 mp	3,265 mp	−13.7	17.7	5.1	3.8
34	33	Carbon black	2.55	3.33	2,546 mp	3,329 mp	−23.5	−0.5	−1.6	−1.4
35	39	Sodium sulfate[l]	2.51	2.35	1,257 tt	1,173 tt	7.2	0.4	0.5	−0.9
36	35	Phenol[m]	2.46	2.98	2,463 mp	2,981 mp	−17.4	11.1	7.2	3.7
37	37	Aluminum sulfate	2.36	2.46	1,182 tt	1,232 tt	−4.1	−5.9	0.7	−0.1
38	36	Acetone	2.12	2.65	2,123 mp	2,653 mp	−20.0	5.3	5.3	2.8
39	38	Cyclohexane	1.97	2.43	1,967 mp	2,425 mp	−18.9	4.0	2.6	0.7
40	43	Calcium chloride[n]	1.97	1.96	983 tt	981 tt	0.2	−4.8	−3.7	−1.2
41	42	Vinyl acetate	1.92	1.98	1,918 mp	1,982 mp	−3.2	17.1	8.2	9.1
42	41	Acrylonitrile	1.83	2.02	1,830 mp	2,018 mp	−9.3	15.2	8.5	5.8
43	44	Isopropyl alcohol	1.79	1.90	1,788 mp	1,900 mp	−5.9	9.8	3.3	−0.7
44	40	Propylene oxide	1.77	2.25	1,767 mp	2,249 mp	−21.4	9.9	3.0	4.2
45	46	Sodium silicate	1.48	1.55	740 tt	777 tt	−4.8	−2.4	0.4	1.6
46	48	Acetic anhydride	1.47	1.51	1,468 mp	1,505 mp	−2.5	0.3	0.6	−0.8
47	47	Sodium tripolyphosphate	1.44	1.51	719 tt	756 tt	−4.9	2.3	−1.4	−5.1
48	49	Titanium dioxide	1.43	1.48	715 tt	741 tt	−3.5	5.7	3.4	0.9
49	50	Ethanol[m]	1.22	1.41	1,224 mp	1,408 mp	−13.1	11.1	−3.0	−4.6
50	45	Adipic acid	1.20	1.80	1,200 mp	1,800 mp	−33.3	11.0	−2.2	1.0
		TOTAL INORGANICS IN TOP 50	**369.35**	**374.39**			**−1.3%**	**4.2%**	**4.0%**	**2.9%**
		TOTAL ORGANICS IN TOP 50	**173.51**	**189.03**			**−8.2%**	**13.8%**	**7.1%**	**4.5%**
		GRAND TOTAL OF TOP 50	**542.86**	**563.42**			**−3.6%**	**7.2%**	**5.0%**	**3.3%**

a Revised. **b** tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons. **c** Except refractory dolomite. **d** Original solution. **e** Synthetic and natural. **f** Primary solution. **g** All grades. **h** All forms. **i** Includes both acid and ester without double counting. **j** 37% by weight. **k** Rubber grade. **l** High and low purity. **m** Synthetic only. **n** Solid and liquid.
Sources: Bureau of the Census, Bureau of Mines, International Trade Commission, C&EN estimates

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Polymers were especially hard hit in 1980

	Billions of lb 1980	Common units 1980	1979	1978	1975	1970	Average annual growth 1979–80	1978–79	1975–80	1970–80
PLASTICS (millions of lb)										
Thermosetting resins	**4.09**	**4,094**	**4,857**	**4,488**	**2,888**	**2,666**	**−15.7%**	**8.2%**	**7.2%**	**4.4%**
Phenolic and other tar acid resins	1.50	1,499	1,781	1,617	1,052	1,186	−15.8	10.1	7.3	2.4
Polyesters (unsaturated)	0.95	947	1,147	1,209	833	569	−17.4	−5.1	2.6	5.2
Urea resins	1.17	1,165	1,367	1,122	690	746	−14.8	21.8	11.0	4.6
Epoxies (unmodified)	0.32	315	361	299	198	165	−12.7	20.7	9.7	6.6
Melamine resins	0.17	167	200	202	115	a	−16.5	−1.0	7.8	a
Thermoplastic resins	**25.37**	**25,367**	**28,083**	**25,186**	**16,729**	**13,540**	**−9.7%**	**11.5%**	**8.7%**	**6.5%**
Low-density polyethylene	7.29	7,291	7,793	7,111	4,740	4,458	−6.4	9.6	9.0	5.0
Polyvinyl chloride and copolymers	5.47	5,470	6,119	5,723	3,636	3,115	−10.6	6.9	4.2	5.8
Polystyrene and copolymers	4.55	4,553	5,320	5,077	4,005	3,550	−14.4	4.8	2.6	2.5
High-density polyethylene	4.41	4,405	5,010	4,201	2,446	1,604	−12.1	19.3	12.5	10.6
Polypropylene and copolymers	3.65	3,648	3,841	3,074	1,902	1,031	−5.0	25.0	13.9	13.5
TOTAL[b]	**29.46**	**29,461**	**32,940**	**29,674**	**19,617**	**16,206**	**−10.6%**	**11.0%**	**8.5%**	**6.2%**
SYNTHETIC FIBERS (millions of lb)										
Cellulosics	**0.81**	**806**	**930**	**905**	**749**	**1,373**	**−13.3%**	**2.8%**	**1.5%**	**−5.2%**
Rayon	0.49	490	606	597	436	875	−19.1	1.5	2.4	−5.6
Acetate	0.32	316	324	308	313	498	−2.5	5.2	0.2	−4.5
Noncellulosics	**8.74**	**8,741**	**9,433**	**8,696**	**6,421**	**4,053**	**−7.3%**	**8.5%**	**6.4%**	**8.0%**
Polyester[c]	3.99	3,989	4,178	3,800	2,995	1,477	−4.5	9.9	5.9	10.5
Nylon	2.36	2,358	2,721	2,550	1,857	1,355	−13.3	6.7	4.9	5.7
Glass fiber	0.87	867	1,014	923	547	467	−14.5	9.9	9.7	6.4
Acrylic[d]	0.78	779	761	726	525	492	2.4	4.8	8.2	4.7
Olefin[e]	0.75	748	759	692	497	262	−1.4	9.7	8.5	11.1
TOTAL[b]	**9.55**	**9,547**	**10,363**	**9,601**	**7,170**	**5,426**	**−7.9%**	**7.9%**	**5.9%**	**5.8%**
SYNTHETIC RUBBER (thousands of metric tons)										
Styrene-butadiene[f]	2.37	1,074	1,378	1,395	1,179	1,332	−22.1%	−1.2%	−1.8%	−2.1%
Polybutadiene	0.69	311	397	377	290	284	−21.7	5.3	1.4	0.9
Neoprene	0.33	151	183	161	144	g	−17.5	13.7	0.9	g
Ethylene-propylene	0.32	144	175	174	84	68	−17.7	0.6	11.4	7.8
Nitrile	0.14	63	75	73	55	64	−16.0	2.7	2.7	−0.2
Other[h]	0.59	266	319	292	188	g	−16.6	9.2	2.7	g
TOTAL[b]	**4.43**	**2,009**	**2,527**	**2,472**	**1,940**	**2,197**	**−20.5%**	**2.2%**	**0.7%**	**−0.9%**

a Data on melamine and urea are combined for 1970. b Totals are for those products listed. Totals may not add because of rounding. c Includes small amounts of anidex, saran, spandex, vinyon, and TFE-fluorocarbon yarn and monofilament. d Includes modacrylic. e Includes vinyon staple and tow. f Excludes high-styrene latex. g Data for neoprene and "other" are combined for 1970. h Includes butyl, polyisoprene, chlorosulfonated polyethylene, polyisobutylene, acrylic, fluoro, polysulfide, and silicone elastomers. **Sources:** Society of the Plastics Industry, Textile Economics Bureau, Rubber Manufacturers Association

index was 187.9 in 1980, off 1.6% from 1979.

Both the chemicals and allied products and the basic chemicals indexes fared worse than the index for nondurable manufacturing, the broader classification to which they belong. The production index for nondurable manufacturing dropped 1.3% in 1980 to 161.1.

The drop in production last year was indeed broad. Of the 50 chemical products on the list, output fell for 40 of them. In 1979, only eight of the chemicals were produced in smaller volume than during the year before. The breadth of the drop in output last year is almost as bad as in the recession of 1975, when it decreased for 42 chemicals then on the list.

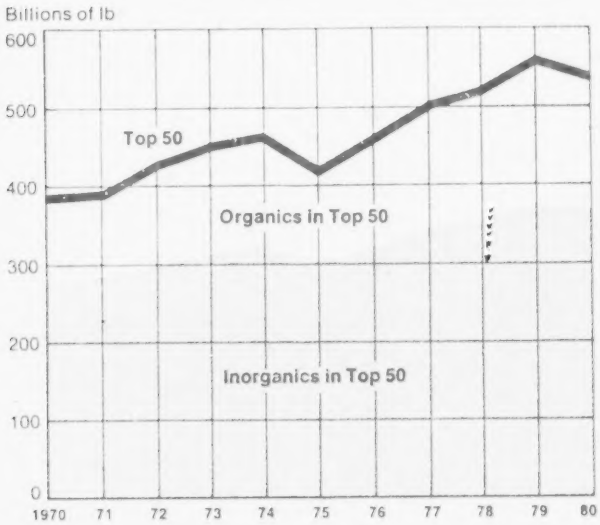
The good year for fertilizer use in the U.S. and exports of fertilizer materials helped keep the results from falling any more than they did. Of the 10 chemicals whose output increased in 1980, four—ammonia, phosphoric acid, ammonium nitrate, and urea—are tied to fertilizer. In fact, the increase for ammonium nitrate of 10.1% represented the second best growth on the list. The greatest output increase was shown by the industrial gas nitrogen, up 14.1% from 1979 to 472 billion cu ft.

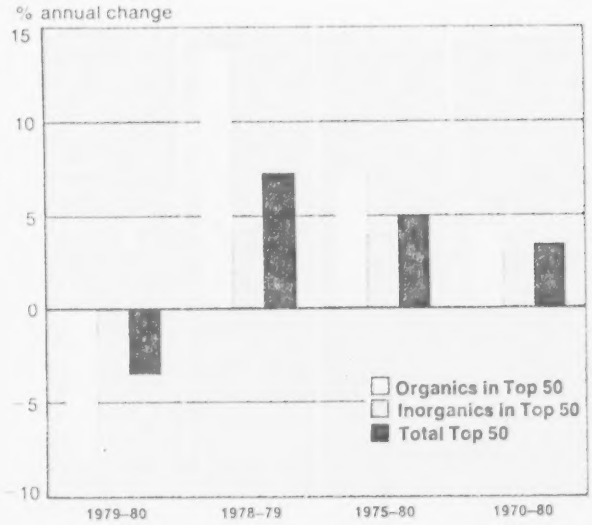
In fact, nitrogen and ammonium nitrate were the only chemicals in 1980 to register gains of more than 10%. In 1979, 17 of the 50 chemicals had gains of more than 10%.

Actually, the situation in 1980 is almost the reverse of 1979. Whereas production of 17 chemicals increased in 1979 more than 10% over 1978, in 1980 15 chemicals had declines of more than 10% from 1979 levels. And in 1979 there were no decreases of more than 10%; in 1980 only two chemicals increased more than 10%.

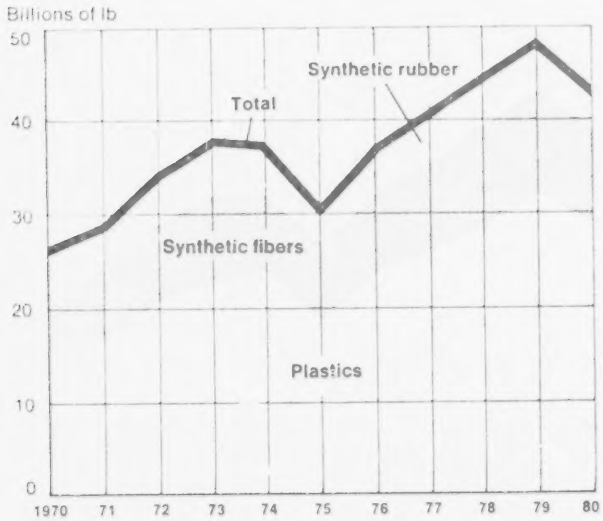
A full 31 of the chemicals changed their rank in 1980 from what they had been in 1979. Sixteen of the chemicals

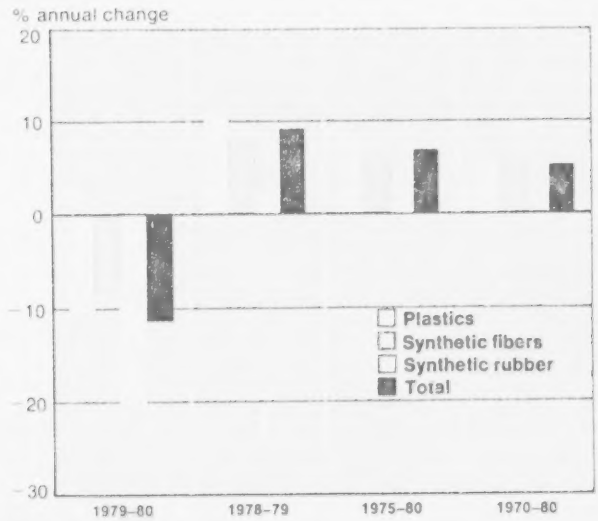
Production of basic chemicals fell for first time since 1975...





...depressed by 11% decrease in polymer production





moved up the list while 15 moved down. However, many of the chemicals that moved up in rank did so not because their production increased but because production of chemicals close to them decreased more than their own. Nine of the 16 chemicals that moved up in rank posted production decreases.

The biggest drop in rank was for adipic acid, which fell to 50th place in 1980 from 45th in 1979. Adipic acid also had the greatest decline in production in 1980, 33.3%. The largest increase in rank was for sodium sulfate, which moved up four places to 35th in 1980 from 39th in 1979.

Organic chemicals, of which there are more on the list than inorganics, led in both number of declines in rank and in number of declines in production. Of the 15 chemical products that moved down on the list, 11 were organic chemicals. And of the 40 products whose production declined, 27 were organics. This represents 93% of the 29 organic chemicals in the Top 50. Production of 13 inorganic chemicals, or 62% of the inorganics listed, decreased.

It is easy to see why the organic chemicals moved down more rapidly in 1980 when one looks at production of downstream polymers. Of all the polymers surveyed by C&EN—plastics, fibers, and rubber—only one, acrylic fiber, increased in production in 1980, and that was just 2.4% over 1979 levels.

Synthetic rubber was the big loser in 1980 among the polymers. Production was off 20.5% to 4.43 billion lb from 1979. Plastics, the largest-volume downstream group, followed with an output decline of 10.6% to 29.46 billion lb.

Long-suffering synthetic fibers had the best performance among the polymers, but it was still bad. Fibers output in 1980 dropped 7.9% to 9.55 billion lb from 1979. □

Top 50 boost chemical sales to $100 billion

David M. Kiefer
C&EN, Washington

The track of last year's recession is apparent in the operating results of the leading U.S. producers of chemicals. For C&EN's Top 50 group—companies ranked by their total worldwide sales of chemicals rather than by their sales of all types of products—the value of chemicals moved into the marketplace generally increased last year. The 50 companies as a whole, for example, sold $100 billion worth of chemicals during the year, an increase of 11% from 1979.

But last year's gain comes nowhere near to matching the 25% increase these companies racked up during 1979. And such improvements as the companies did make most often stemmed from higher selling prices rather than increased physical volume. As raw material and energy costs continued to escalate sharply, prices of key industrial chemicals, plastics, fibers, and agricultural chemicals averaged about 20% higher last year than in 1979, with most of the increase occurring during the year's first half. On the other hand, output of most of the commodity chemicals trailed the previous year. For all basic chemicals and synthetic materials, production for 1980 as a whole was off 6%.

This year's Top 50 group (based on 1980 sales) is comprised of most of the companies that appeared in last year's compilation. And the relative rankings are, for the most part, quite similar to the year before—especially among the 10 highest-ranking firms. This year, however, two major farm supply cooperative organizations, CF Industries and Farmland Industries, are included for the first time; both have big agricultural chemical operations and would have been included among the Top 50 in previous years also had C&EN ranked them at that time. Other than these two, the only addition to the group is Georgia-Pacific, the big forest products and paper producer that has been sharply boosting its chemical and plastics business in recent years (sales of chemicals have nearly doubled since 1978). It replaces Akzona, whose chemical sales were essentially unchanged last year.

C&EN's Top

50

Chemical Producers

Even though the sales gains generally were relatively modest, the Top 50 are noticeably a financially heftier lot than before. Du Pont, for one, became the first U.S. company to push its total worldwide chemical volume past the $10 billion mark. Now, too, 36 producers have chemical sales of more than $1 billion, compared to 32 in 1979 and only 13 five years earlier. And all the companies have sales of more than $600 million. In 1979, three companies with sales below that level were included among the group.

Several other companies have chemical sales in the neighborhood of $600 million. C&EN estimates that both Goodyear Tire and ICI Americas sold about that amount of chemicals in 1980, although neither firm discloses its volume of chemical sales. (Goodyear reports sales of nearly $1 billion of industrial rubber, chemical, and plastics products, but that total includes a considerable amount of industrial belting and hose, tank tracks, packaging films, shoe soles and heels, vinyl film and sheeting, graphic products, and adhesives.) Pennwalt, too, has chemical sales of just over $600 million. A little below that level are companies like Akzona ($575 million in 1980), Cities Service ($557 million), NL Industries ($552 million), and Eli Lilly ($518 million).

Some of the best increases in sales last year stem from a strong demand for fertilizer, both in the U.S. and abroad, coupled with improved prices. As a result, agricultural chemical companies such as Williams' Agrico Chemical, International Minerals, CF Industries, and Farmland Industries bolstered sales 20% or more. Fertilizer business also helped boost the chemical sales of companies like Occidental Petroleum (its sales of agricultural products leaped 44% in 1980), U.S. Steel, Union Oil, and Mobil at a better-than-average clip.

Meanwhile, a handful of companies turned in sales of chemicals in 1980 that were less than they had had in 1979. The greatest drop—that for BASF Wyandotte—reflects the sale or shutdown of several business lines during the year; Wyandotte's sales from continuing operations actually were up 4% during the year. Similarly, National Distillers' lower sales result from the elimination of its European polyethylene business, which had brought in $62 million of sales before it was sold off in 1979. PPG Industries' chemical sa es were undercut, in part, by its withdrawal in 1979 from the chrome chemicals and antifreeze markets, which had provided revenues of about $40 million that year. Goodrich's plastics business was affected adversely by weak demand from its important construction and automobile markets.

In categorizing "chemical" sales, C&EN includes industrial chemicals, plastics and resins, man-made fibers, synthetic rubber, fertilizer and other agricultural chemicals, and various specialty industrial products, such as water treatment chemicals and lubricant additives. Excluded, whenever possible, are such related products as pharmaceuticals, coatings, fabricated plastics, detergents, adhesives, minerals, and finished consumer products.

Individual companies do not necessarily report their financial data in the same way, however. Quite frequently, for example, they will lump sales of fabricated plastics with plastic resins or phosphate rock with fertilizer phosphates. As a result, figures on the chemical sales of one company may not be consistent with those for another, even though C&EN attempts to adjust the data with its own estimates whenever possible. Consequently, the rankings on the opposite page should be viewed as only approximate, especially when two or more companies have sales that are nearly identical. □

Chemicals provide less than half of total sales for most of Top 50 chemical makers

Rank 1980	Rank 1979[a]	Company	Chemical sales 1980 ($ millions)	Change from 1979	Total sales 1980 ($ millions)	Chemical sales as % of total sales	Industry classification	TOTAL COMPANY Net income 1980 ($ millions)	Profit margin[b] Per cent 1980	Profit margin[b] Rank 1980	Profit margin[b] Rank 1979	Return on stockholders' equity[c] Per cent 1980	Return on stockholders' equity[c] Rank 1980	Return on stockholders' equity[c] Rank 1979
1	1	Du Pont	$10,250	6%	$ 13,652	75%	Basic chemicals	$ 706	5.2%	27	14	12.6%	34	17
2	2	Dow Chemical	7,217	9	10,626	68	Basic chemicals	805	7.6	12	8	18.1	17	8
3	3	Exxon	6,936	19	103,143	7	Petroleum	5650.1	5.5	23	30	22.2	7	11
4	4	Union Carbide	5,650	7	9,994	57	Basic chemicals	673	6.7	15	23	14.1	29	35
5	5	Monsanto	5,453	5	6,574	83	Basic chemicals	148.8	2.3	44	31	5.3	46	41
6	6	Celanese	3,200	6	3,348	96	Basic chemicals	122	3.6	41	37	11.1	40	36
7	7	Shell Oil	3,089	19	19,830	16	Petroleum	1542	7.8	11	12	19.0	15	26
8	9	W. R. Grace	2,733[d]	14	6,101	45	Specialty chemicals	283.8	4.7	34	38	15.8	23	34
9	8	Gulf Oil	2,569[d]	5	26,483	10	Petroleum	1407	5.3	26	29	14.6	26	30
10	13	Occidental Petroleum	2,458[d]	23	12,476	20	Petroleum	710.8	5.7	20	27	31.2	3	1
11	10	Allied	2,450	14	5,519	44	Basic chemicals	289	5.2	27	39	15.0	25	40
12	12	Standard Oil (Ind.)	2,235	11	26,133	9	Petroleum	1915.3	7.3	13	10	20.4	12	16
13	11	Hercules	2,095	3	2,485	84	Basic chemicals	114.0	4.6	36	15	11.3	38	15
14	16	Atlantic Richfield	1,945	17	23,744	8	Petroleum	1651.4	6.8	14	16	22.2	8	11
15	14	American Cyanamid	1,861[d]	10	3,454	54	Basic chemicals	159.2	4.6	35	32	11.1	39	39
16	15	Phillips Petroleum	1,858	10	13,377	14	Petroleum	1069.6	8.0	10	6	21.7	10	7
17	17	Eastman Kodak	1,837	17	9,734	19	Photographic equipment	1153.6	11.9	3	2	19.1	14	14
18	19	Stauffer Chemical	1,643	11	1,695	97	Basic chemicals	136.6	8.1	9	7	14.6	27	27
19	18	Rohm & Haas	1,609	9	1,725	93	Basic chemicals	93.7	5.4	24	24	13.3	31	32
20	22	Tenneco	1,565	11	13,226	12	Petroleum	726	5.5	22	33	15.2	24	28
21	23	Mobil	1,558	18	59,510	3	Petroleum	281.3	4.7	32	36	21.5	11	13
22	20	Borden	1,548[d]	6	4,596	34	Dairy products	147.9	3.2	42	42	12.0	35	42
23	21	Ethyl Corp.	1,517[d]	5	1,741	87	Basic chemicals	89.7	5.2	29	26	12.8	33	31
24	25	U.S. Steel	1,437	19	12,492	12	Steel	458.9	3.7	40	—	8.7	43	—
25	28	Texaco	1,346	29	51,196	3	Petroleum	2240.2	4.4	37	34	17.9	18	24
26	24	Diamond Shamrock	1,307	6	3,143	42	Basic chemicals	201.2	6.4	18	13	16.2	22	19
27	27	Air Products[e]	1,262	19	1,421	89	Basic chemicals	115.5	8.1	8	11	17.4	20	20
28	32	CF Industries	1,233[d]	21	1,233	100	Agricultural chemicals	187.3[f]	15.2	1	3	38.7	1	2
29	26	FMC	1,215	7	3,482	35	Farm and construction machinery	142.7	4.1	38	35	11.5	37	38
30	36	Williams Cos.	1,171[d]	28	2,073	57	Agricultural chemicals	138.7	11.8	4	41	14.4	28	44
31	30	Standard Oil of Calif.	1,155	11	40,479	3	Petroleum	2401	5.9	19	25	21.7	9	9
32	38	Ciba-Geigy	1,115	32	1,690	66	Specialty chemicals	na	na	—	—	na	—	—
33	33	Ashland Oil	1,100	8	8,118	14	Petroleum	205.1	2.5	43	43	17.6	19	18
34	35	Mobay Chemical	1,069	12	1,069	100	Basic chemicals	54.1	5.1	30	22	13.0	32	22
35	37	Union Oil of Calif.	1,048	21	9,984	10	Petroleum	647.0	6.5	17	18	18.6	16	21
36	31	B. F. Goodrich	1,022	−2	3,080	33	Rubber products	61.7	2.0	45	44	6.4	45	45
37	43	International Minerals[g]	974	24	1,790	54	Agricultural chemicals	145.9	8.2	7	9	16.6	21	29
38	34	PPG Industries	964	−1	3,158	31	Glass products	209.2	6.6	16	17	13.9	30	25
39	29	BASF Wyandotte	917	−12	917	100	Basic chemicals	(65.1)[b]	—	—	48	—	—	47
40	45	Lubrizol	902	24	902	100	Specialty chemicals	111.5	12.4	2	1	24.6	4	3
41	40	American Hoechst	896	10	1,290	69	Basic chemicals	(10)[h]	—	—	45	na	—	—
42	39	Olin	883	7	1,853	48	Basic chemicals	33.9	1.8	46	40	4.5	47	43
43	42	Conoco	875	10	18,301	5	Petroleum	1026.2	5.6	21	19	22.4	6	5
44	41	Reichhold Chemicals	807	2	885	91	Basic chemicals	16.1	1.8	47	47	7.8	44	46
45	44	National Distillers	744	−4	2,055	36	Alcoholic beverages	110.6	5.4	25	20	9.4	42	37
46	47	Farmland Industries[i]	734	20	4,745	15	Agricultural supplies	182.5[f]	3.8	39	46	34.4	2	10
47	48	Dow Corning	681	12	681	100	Specialty chemicals	73.9	10.8	6	4	19.6	13	6
48	—	Georgia-Pacific	661[d]	22	5,016	13	Lumber and wood products	244	4.9	31	21	11.7	36	23
49	48	Borg-Warner	631	6	2,673	24	Automobile equipment	126.1	4.7	33	28	10.9	41	33
50	49	Nalco Chemical	617	7	617	100	Specialty chemicals	72.3	11.7	5	5	23.6	5	4

a Revised. b Net income as a percentage of net sales. c Net income as a percentage of net worth. d Chemical sales include significant amounts of nonchemical products, such as fabricated plastics, coatings, adhesives, minerals, and the like. e For the year ended Sept. 30. f Company is organized as a farm cooperative; net income represents patronage refunds plus net earnings or net savings. g For the year ended June 30. h Deficit. i For the year ended Aug. 31. na = not available.

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NOTE

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Chemical & Engineering NEWS
May 11, 1981

Computer's role in chemistry growing despite loss of national center Page 28

STRATEGIC MINERALS POLICY

Mining seabed could help reduce dependence on imports Page 20

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Volume 59, Number 19
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Chemical & Engineering NEWS

Cover: Row of freefall grab samplers aboard research vessel *Prospector* poised for dropping to ocean floor to obtain manganese nodules. Each sampler is equipped with radio, flasher, chemical light, and flag to aid in locating it after it returns to the surface. Photo by W. T. Allen, Deepsea Ventures

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- ***Exiled Soviet dissident Andrei Sakharov*** *sends message on responsibilities of scientists to meeting in his honor.* ***Page 5***
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- ***Most recent investigation of layoffs*** *of chemical professionals by society's Committee on Professional Relations shows guidelines are not being followed.* ***Page 33***
- ***Votes of ACS councilors*** *on proposed amendment limiting directors' terms recorded at Atlanta meeting.* ***Page 34***

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Profits, profit margins fall in first quarter

Small companies led earnings decline in U.S. basic chemicals industry, but their profitability remains higher than that of large firms

William F. Fallwell
and William J. Storck
C&EN, New York

Chemicals in the first quarter made hardly anyone proud. Earnings were off at the major U.S. basic chemical companies. The oil companies, in a profit slide of their own, had horrid results in petrochemicals. At other diversified nonchemical companies, chemical operations generally were off with a few exceptions, notably caustic soda.

Thus, chemicals suffered a profits relapse after a fairly healthy fourth quarter in 1980.

Chemical companies, like the others, could not maintain the momentum that came in the fourth quarter. Earnings of the 40 largest U.S. chemical companies (those reporting to date) fell an average of 7.9% to a combined $1.65 billion in the first quarter from that of a year ago.

Sales for the 40 chemical companies were not outstanding either. Combined sales in the first quarter increased only 6.3% to $25.6 billion.

Since the producer price index for chemicals and allied products increased 12.6% in first-quarter 1981 over the same three months last year, physical volume was necessarily off for the chemical companies.

The 20 largest companies—and the ones with the biggest stake in basic chemicals—saw earnings drop an average of 7.1% to a combined $1.41 billion from the first quarter last year. Sales at most of these companies continued to climb, however. For all 20, sales increased 6.3% in the quarter to a combined $22.9 billion.

The smaller companies' performance was something of a surprise. They have outperformed the larger companies for so long that it was taken for granted. But in the first quarter, combined earnings for the 20 smaller chemical companies fell 12.4% from first-quarter 1980 to about $237 million. This ends a string of quarters back to mid-1978 in which earnings growth at the smaller, more specialized companies was greater than that for the larger companies.

However, profit margins (net earnings as a percentage of sales) at the smaller companies remained higher than at the larger companies in the first quarter. Profitability at the smaller companies averaged 8.8% compared to 6.2% for the larger firms, giving an overall average of 6.4% for the 40 companies. This is down considerably from a year ago, when the smaller firms averaged 10.6% and the big companies averaged 7.0%. The average for all companies in the first quarter last year was 7.4%.

Some smaller, specialty companies posted big earnings contractions in the first quarter. For instance, earnings at Lubrizol were off 35%, and at Loctite 52%.

The bigger declines seemed to be at the companies with interests in fertilizers, especially phosphates. For example, First Mississippi's earnings dropped 92% and Beker's decreased 69%.

At the many diversified nonchemical companies with a major stake in agricultural chemicals, success in the first quarter also depended on not having much to do with phosphates. Phosphate-heavy Occidental Petroleum saw chemical profits descend to break-even because of poor markets. But agricultural chemical operations contributed to profit improvements at Esmark, Northwest Industries (Velsicol), and Kaiser Aluminum & Chemical.

Two other earnings influences that did little good for chemical producers in the first quarter were U.S. plastics sales and European chemical sales in general. For example, both got in the way of Uniroyal's fast growth in chemical profits. Uniroyal's chemical operations had to pause in the first quarter with a 10% drop from first-quarter 1980, even though sales rose 13%. The company says that its chemical profits were hit by the European recession and weak pricing of vinyl chloride for vinyl plastics. Uniroyal plans to get out of vinyl chloride production with sale of its 50% interest in Monochem to Borden in January 1982 (C&EN, April 20, page 10).

A good hint at the main cause of trouble in the vinyl plastics chain comes from Johns-Manville. Construction-oriented Johns-Manville is a major producer of polyvinyl chloride pipe, PVC's largest outlet. In the first quarter, the company reports pipe sales flat and almost no profits. With such a financial situation downstream and considerable overcapacity in both polymer and monomer, the vinyl product line is in trouble.

Another major plastic with problems is polyethylene. U.S.I. Chemicals, the major profits source at National Distillers, says that its polyethylene products suffered declining sales volume and higher raw material costs in the first quarter. Overall U.S. sales in the leading plastic, low-den-

Chemical industry leaders for first-quarter 1981

Sales		Earnings[a]		Profitability	
Rank	$ Millions		$ Millions		Earnings as % of sales
1 Du Pont	$3654.0	Du Pont	$201.0	Texasgulf	24.1%
2 Dow Chemical	2896.9	Union Carbide	178.0	Freeport-McMoRan	21.8
3 Union Carbide	2639.6	Monsanto	176.0	Great Lakes Chemical	15.2
4 Monsanto	1900.0	Dow Chemical	128.9	Stauffer Chemical	13.9
5 Allied Corp.	1582.0	Stauffer Chemical	87.9	Lawter International	12.8
6 W. R. Grace	1489.1	Allied Corp.	84.0	International Flavors	12.3
7 Celanese	911.0	W. R. Grace	83.0	Nalco Chemical	12.2
8 American Cyanamid	887.0	Texasgulf	66.3	Petrolite	9.9
9 Diamond Shamrock	865.0	PPG Industries	52.5	Williams Cos.	9.6
10 PPG Industries	809.4	Diamond Shamrock	48.0	Monsanto	9.3

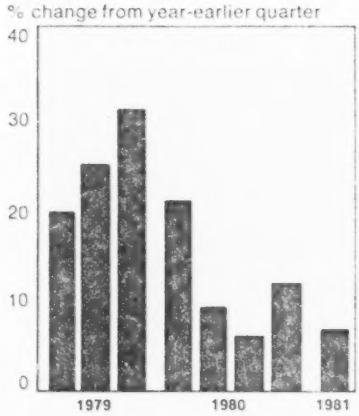
a After taxes. **Note:** For 40 chemical companies listed on page 14.

Chemical industry 1981 first-quarter results

- Sales rose 7%
- Earnings fell 8%
- Profit margins dropped
- Production increased
- Prices up more than 12%

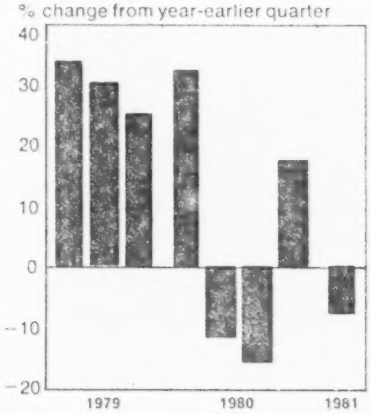
Sales

% change from year-earlier quarter



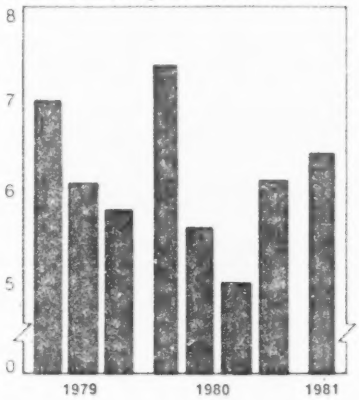
Earnings

% change from year-earlier quarter



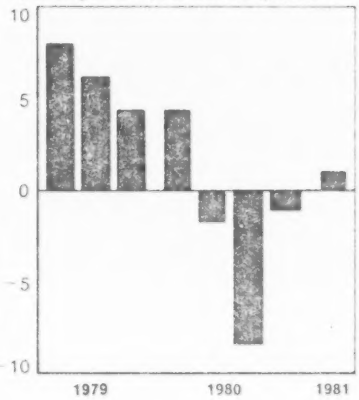
Profit margins

After-tax earnings as % of sales



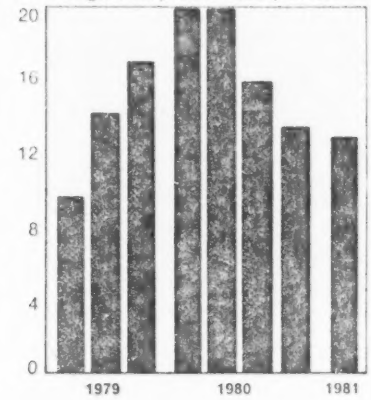
Production

% change from year-earlier quarter



Prices

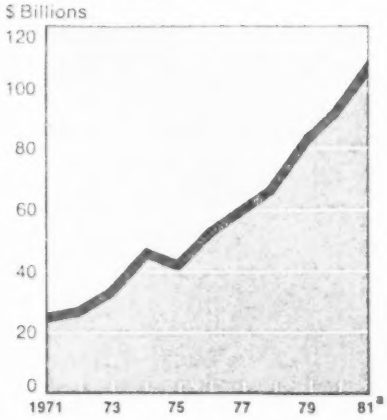
% change from year-earlier quarter



1981 likely will see sales up 15% to top $100 billion, while earnings will rise about 10%

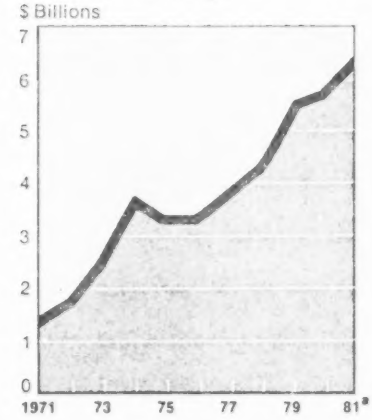
Annual sales

$ Billions



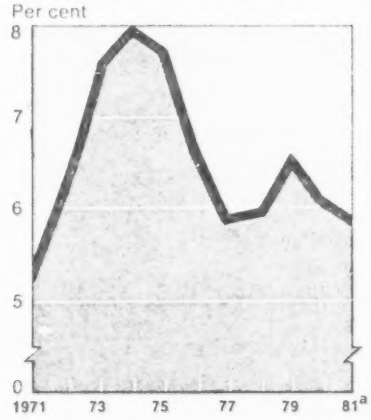
Annual earnings

$ Billions



Annual profit margins

Per cent



[a] C&EN estimates. **Note:** All sales, earnings, and profit margin data are based on the combined performance of the 40 largest chemical makers listed on page 14.

Profits at chemical companies fall in first quarter, led by small firms

	FIRST-QUARTER 1981						12-MONTH RUNNING DATA			
	Sales	Earnings	Change from 1980		Profit margin[a]		Change from 1980		Profit margin[a]	
	($ millions)		Sales	Earnings	1981	1980	Sales	Earnings	1981	1980
Du Pont	$ 3,654.0	$ 201.0	2%	−16%	5.5%	6.7%	5%	−30%	4.9%	7.4%
Dow Chemical	2,896.9	128.9	3	−44	4.4	8.2	7	−22	6.1	8.4
Union Carbide[d]	2,639.6	178.0	3	−19	6.7	8.6	5	−7	6.0	6.8
Monsanto	1,900.0	176.0	4	7	9.3	9.0	4	−35	4.0	6.4
Allied Corp.	1,582.0	84.0	14	24	5.3	4.9	17	54	5.6	4.2
W. R. Grace	1,489.9	83.0	9	26	5.6	4.8	14	24	4.8	4.4
Celanese	911.0	36.0	8	nc	4.0	4.3	5	−16	3.6	4.5
American Cyanamid	887.0	47.1	7	24	5.3	4.6	8	2	4.8	5.1
Diamond Shamrock	865.0	48.0	15	−15	6.5	7.5	25	−6	5.9	7.9
PPG Industries	809.4	52.5	2	−4	6.5	6.9	1	−8	6.4	7.1
B. F. Goodrich[e]	780.4	8.3	2	−51	1.1	2.2	2	−31	1.6	2.4
Hercules	667.0	35.5	3	5	5.3	5.2	3	−14	4.9	5.8
Stauffer Chemical	629.3	87.9	8	26	13.9	11.9	8	−2	8.0	8.9
International Minerals[f]	563.2	47.0	23	−15	8.3	12.0	18	nc	8.1	9.5
Olin	521.7	28.4	9	27	5.4	4.6	5	6	4.2	4.2
Williams Cos.	495.6	47.4	3	45	9.6	6.8	10	56	7.2	5.1
Rohm & Haas	478.7	27.4	10	1	5.7	6.2	8	−4	5.3	6.0
Ethyl Corp.	425.3	20.5	−3	−3	4.8	4.8	nc	−9	5.2	5.7
Air Products	413.0	36.9	14	8	8.9	9.0	11	6	7.9	8.3
Witco Chemical	323.5	5.9	13	−10	6.1	7.2	18	−17	3.0	4.3
Akzona	308.8	2.7	5	−49	0.9	1.8	1	−89	0.2	2.0
Pennwalt	295.0	7.7	nc	−32	2.6	3.9	7	−21	3.3	4.5
Texasgulf	275.3	66.3	−2	−14	24.1	27.7	22	66	29.0	21.1
Reichhold Chemicals	238.9	4.0	1	−5	1.7	1.8	−2	15	1.8	1.5
Freeport-McMoRan	224.7	49.0	37	14	21.8	26.3	35	32	21.1	21.6
Lubrizol	224.[illegible]	18.9	nc	−35	8.4	13.0	15	−1	11.0	12.7
Thiokol	172.5	8.5	17	−14	4.9	6.7	20	−30	4.2	7.3
Nalco Chemical	156.8	19.2	6	18	12.2	11.0	6	17	12.0	10.9
International Flavors	123.4	15.2	1	−16	12.3	14.9	5	−6	13.4	14.9
Mallinckrodt	121.3	10.1	8	12	8.3	8.0	11	11	8.2	8.2
Liquid Air	109.6	9.1	3	11	8.3	7.7	7	10	7.1	6.9
Petrolite	71.0	7.0	20	37	9.9	8.6	30	59	10.1	8.3
First Mississippi	64.2	0.4	52	−92	0.6	11.6	45	24	6.8	7.9
Crompton & Knowles	59.9	1.8	−3	2	3.0	2.8	−1	nc	3.2	3.2
Loctite	56.6	3.0	12	−52	5.3	12.4	8	−48	6.6	13.6
Baker Industries	52.2	3.4	−30	−69	6.5	14.5	16	−7	7.3	9.1
Stepan Chemical[g]	49.6	1.2	26	100	2.4	1.5	12	36	3.6	2.9
Essex Chemical	39.9	0.9	19	29	2.2	2.1	20	30	3.6	3.3
Great Lakes Chemical	34.8	5.3	3	nc	15.2	15.6	nc	−4	14.8	15.5
Lawter International	23.5	3.0	16	−6	12.8	15.8	19	4	14.0	16.0
Total 20 largest companies	**$22,932.5**	**$1410.7**	**6.3%**	**−7.1%**	**6.2%**	**7.0%**	**7.6%**	**−15.0%**	**5.0%**	**6.4%**
Total 20 other companies	**$ 2,702.9**	**$ 236.7**	**6.3%**	**−12.4%**	**8.8%**	**10.6%**	**11.5%**	**16.0%**	**9.6%**	**9.2%**
GRAND TOTAL	**$25,635.4**	**$1647.4**	**6.3%**	**−7.9%**	**6.4%**	**7.4%**	**8.0%**	**−10.5%**	**5.5%**	**6.7%**

a After-tax income as a percentage of sales. b Fully diluted before nonrecurring items and extraordinary charges for operations. c As of April 30. d Excludes $217.3 million nonrecurring credit in first-quarter 1980. e Excludes $18 million extraordinary gain in first-quarter 1981 and $3.5 million nonrecurring gain in first-quarter 1980. f Excludes $14 million charge in first-quarter 1980. g Includes nonrecurring item. nc = no or insignificant change.

sity polyethylene, were down 3% from 1980 for the first two months of 1981, reports the committee on resin statistics of the Society of the Plastics Industry from data compiled by accountants Ernst & Whinney.

In the inorganics, European markets also are the wrong ones to have at the moment for chemical producers. For example, NL Industries says that its chemical results in the first quarter were worse than last year, despite improved specialty lines, because titanium dioxide pigment operations in both the U.S. and Europe were depressed by weak demand and associated production curtailments.

The European market also dissolved away earnings at GAF and Ferro. GAF says that, aside from Europe, its U.S. chemical sales and profits were up in the first quarter. Overall, however, GAF's chemical profits were virtually unchanged from a year earlier. Ferro says that the European recession was the main reason its corporate earnings fell 37% in the first quarter from a year ago.

Although such results were widespread in U.S. and foreign operations

STOCK MARKET DATA[c]

Earnings per share[b]		Stock price			Price-earnings ratio	Annual indicated dividend	Dividend yield, % of price
	Recent		Recent 12 months				
1st qtr	12 months	April 30	High	Low	April 30		
$1.35	$4.58	$49 3/4	$52	$35 3/4	11	$2.40	4.8%
0.70	3.78	34 3/4	39	30 1/4	9	1.80	5.2
2.64	9.82	57 3/8	62 1/8	37 1/8	6	3.20	5.6
4.78	7.30	71 1/8	77 3/4	44 7/8	16	3.80	5.3
2.33	8.86	52 1/2	61 3/4	44 1/2	7	2.40	4.6
1.72	6.35	51 3/8	63 1/2	33 1/2	8	2.30	4.5
2.34	9.27	61 1/2	68 3/4	44 1/8	8	3.80	6.2
0.98	3.68	35 1/8	35 1/2	24 5/8	10	1.60	4.6
0.85	3.45	32 1/4	38 7/8	26 1/8	9	1.68	5.2
1.57	6.24	51	58 1/4	28 1/4	8	2.36	4.6
0.43	2.78	26 3/8	28 1/8	17 3/4	9	1.56	5.9
0.80	3.53	24 5/8	26 3/8	15 7/8	9	1.20	4.9
2.00	3.18	25 1/2	27 3/4	16	7	1.32	5.2
1.71	6.38	48	66 1/2	30 1/4	7	2.60	5.4
1.18	3.39	26 1/8	27	15 1/4	16	1.10	4.2
1.58	5.68	33 3/8	49 7/8	27	6	1.10	3.3
2.12	7.28	61	62 1/8	35	8	2.32	3.8
1.44	4.34	31 7/8	36 1/2	23 7/8	8	1.50	4.7
1.30	4.20	45 7/8	54 1/4	33 1/2	11	0.80	1.7
0.64	3.71	27 1/2	33 3/4	22	7	1.60	5.8
0.22	0.19	14 1/8	15 1/2	9 1/2	74	0.80	5.7
0.74	3.74	31 1/2	36	25 3/4	10	2.20	7.0
1.69	7.24	53 3/4	67 7/8	32 3/8	7	2.00	3.7
0.47	1.87	14 5/8	16	10 7/8	8	0.48	3.3
0.71	3.96	34 3/4	40 1/2	32 5/8	9	0.60	1.7
0.97	5.22	58 5/8	83 3/8	56	11	2.16	3.7
0.71	2.56	37 1/2	39	25 3/4	14	1.00	2.7
0.95	3.75	54 1/8	58 1/4	30	15	2.00	3.7
0.86	2.09	21	27 1/2	18 1/2	10	0.92	4.4
1.02	3.76	51 1/2	55 1/2	30 1/4	8	1.40	2.7
0.41	2.40	27	34 1/2	19 3/4	10	1.40	5.2
1.18	4.51	39 3/4	44 3/4	39 3/4	11	0.80	2.0
0.02	1.87	18 7/8	30 3/4	18	19	0.24	1.3
0.53	3.37	26	27	17 3/4	8	1.36	5.2
0.30	1.40	27 1/2	38	26 1/2	20	0.56	2.0
0.29	1.85	16	25	10 7/8	6	—	—
0.61	3.20	39 1/8	43 3/4	16 7/8	12	1.00	2.6
0.35	2.16	15 3/8	19 3/8	10 1/2	8	0.80	5.2
0.75	2.67	56	58 1/2	39	21	0.44	0.8
0.26	1.03	13 1/8	15 1/8	10 1/8	13	0.66	5.0

of chemical producers in the first quarter, they weren't universal. Consider caustic soda, in tight supply all three months. One producer, Vulcan Materials, reports that its inorganic product lines (notably caustic soda) were the main reason for a 44% jump in pretax chemical earnings from a year ago. By pretax profits, Vulcan is mainly a chemical company, with about three fourths in this area.

Fortunately, overall corporate results in the first quarter were improved at most companies outside the basic chemical industry with chemical operations, except oil and natural gas companies. Oil companies now are taking their lumps after a meteoric profits rise in the past two years. □

Ground rules for the C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 40 largest U.S. basic chemical companies and from 50 diversified companies, each with more than $200 million in annual chemical sales.

The 40 largest chemical firms included in the table on this page produce 50 to 60% of chemicals sold in the U.S. The table of nonchemical firms on pages 16 and 17 is divided into two groups: 20 oil and gas companies specializing in basic petrochemicals, and major diversified firms with large chemical operations. In both cases, chemical sales are more than $200 million annually.

Also included is a state-of-the-industry page. These graphs give quarterly comparisons for the past two years on five specific measures for the 40 largest chemical firms, plus annual data for the past decade for the same group.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics; organic intermediates and inorganic compounds; polymers such as plastics and fibers; agricultural chemicals; and specialty derivatives. The list does not include companies whose primary business is formulating or fabricating products made from purchased process chemicals. By the government's Standard Industrial Classification code, the survey's chemicals would fall into SIC categories 281, 282, 286, 287, and, in part, 289.

In listing earnings the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included. Earnings per share are given with full dilution for convertible issues of securities. For firms with fiscal years, data are given for the most recent quarter.

In other definitions, profit margin is after-tax earnings as a percentage of net sales. The 12-month indicated dividend is the latest announced quarterly dividend multiplied by four with year-enders. Price/earnings multiples are for trailing 12-month earnings per share.

Twelve-month earnings per share are for the year ending with the latest quarter. Yield is the indicated annual dividend as a percentage of latest stock price. Shares outstanding are generally averages for latest quarter.

Earnings are hard hit at oil companies but recover at many diversified chemical producers

	Chemical sales as % of total sales	FIRST-QUARTER 1981 Total sales ($ millions)	Earnings	Change from 1980 Sales	Earnings	Profit margin[a] 1981	1980	STOCK MARKET DATA Earnings per share 1st qtr	Recent 12 months	Stock price April 30	12-Month high
OIL AND GAS COMPANIES											
Exxon	7%	$30,323.0	$1600.0	10%	−17%	5.3%	7.0%	$3.70	$12.31	68 1/2	88 3/4
Mobil[b]	3	17,095.0	640.0	12	−24	3.7	5.5	3.01	12.30	62 3/4	88 1/2
Texaco[b]	3	15,453.0	658.0	10	17	4.3	4.5	2.45	8.55	37 1/4	54 3/8
Standard Oil of California	3	11,988.0	666.0	15	6	5.6	6.0	1.95	7.14	41 3/8	51 3/4
Gulf Oil	10	7,874.0	303.0	2	−22	3.9	5.0	1.55	6.26	33 3/4	52 3/4
Standard Oil (Ind.)	9	7,853.1	376.7	22	−35	4.8	8.9	1.29	5.88	57 1/8	99 1/2
Atlantic Richfield	8	7,132.3	346.5	31	−19	4.9	7.8	1.39	5.85	49 3/8	74 3/8
Shell Oil	17	5,413.0	361.0	13	−3	6.7	7.8	1.17	4.95	39 7/8	65 1/2
Conoco	5	5,400.0	250.9	26	−24	4.7	7.6	2.33	8.80	49 1/2	73
Phillips Petroleum	17	4,230.0	270.8	25	−5	6.4	8.4	1.78	6.94	40 7/8	62 7/8
Sun Co.	3	4,000.0	120.0	29	−52	3.0	8.1	0.95	5.15	35 1/4	59 5/8
Tenneco	12	3,809.0	194.0	15	9	5.1	5.4	1.51	5.84	41 3/8	58 3/8
Occidental Petroleum	19	3,400.0	259.4	3	−7	7.6	8.4	3.05	7.99	30	39 1/8
Getty Oil	2	3,294.6	230.2	45	7	5.6	7.6	2.80	10.65	66	108 1/4
Standard Oil (Ohio)	4	3,100.0	520.4	15	15	16.8	16.7	2.12	7.65	50 7/8	91 1/2
Union Oil	10	2,670.0	154.5	12	1	5.8	6.4	0.89	3.74	35 1/2	56 1/2
Cities Service	7	2,299.2	55.7	4	−66	2.4	7.7	0.69	4.38	45 3/8	61 1/4
Ashland Oil	13	2,151.3	7.2	6	−85	0.3	2.3	0.01	4.32	33 1/2	45 3/4
El Paso	14	1,000.9	30.9	19	4	3.1	7.7	0.65	2.31	22 7/8	29 1/2
Kerr-McGee	14	916.1	43.3	17	−8	4.7	6.0	1.67	6.87	74 1/8	93
DIVERSIFIED MANUFACTURERS											
Engelhard Minerals	1	6,410.5	76.0	8	−46	1.1	2.4	1.10	6.80	43 3/4	64 3/8
General Electric	4	6,088.0	359.0	4	5	5.9	5.8	1.57	6.72	65 5/8	69 7/8
U.S. Steel[c]	12	3,399.4	270.9	7	144	8.0	3.5	2.91	7.45	34 1/8	35 1/4
Procter & Gamble	4	2,948.7	181.3	6	−4	6.2	6.8	2.20	7.94	71 3/4	82 3/4
Dart & Kraft	8	2,402.1	96.5	4	−5	4.0	4.4	1.77	6.94	49	52 1/8
Eastman Kodak	19	2,305.3	249.1	8	29	10.8	9.0	1.54	7.49	76 3/4	85 3/8
Goodyear Tire	6	2,217.7	43.1	10	−15	1.9	2.5	0.59	3.07	19 1/4	20 1/4
3M	15	1,582.0	142.7	6	−15	9.0	11.2	1.22	5.57	60 1/2	65
Georgia-Pacific	13	1,348.0	52.0	10	4	3.9	4.1	0.48	2.29	29 1/4	32 3/8
Aluminum Co. of America	10	1,299.1	101.2	0	−30	7.8	11.0	1.37	5.70	33 3/4	37 1/2
Borden	34	1,052.8	32.2	−2	5	3.1	2.9	1.05	4.90	27 1/2	29 7/8
FMC	35	886.2	41.4	1	1	4.7	4.7	1.14	3.95	33 1/8	35 3/4
Kaiser Aluminum	15	834.2	68.1	2	−7	8.2	8.9	1.60	5.49	24 1/8	30 1/4
Pfizer	14	818.2	72.1	15	11	8.8	9.2	0.96	3.55	54 1/2	54 7/8
Eli Lilly	20	812.6	124.8	13	13	15.4	15.5	1.65	4.70	64 5/8	68 3/4
Northwest Industries	7	810.0	51.6	23	69	6.4	4.6	1.67	5.72	49	53
Esmark	20	733.8	11.7	25	58	1.6	1.2	1.03	3.35	64 5/8	69 7/8
Merck	15	725.3	111.8	11	10	15.4	15.5	1.50	5.69	91	96 3/8
Martin Marietta	10	717.5	39.7	27	15	5.5	6.1	1.59	7.75	70 5/8	75
Borg-Warner	24	676.0	34.6	−1	−4	5.1	5.3	1.60	5.77	49 1/2	50 1/4
NL Industries	26	605.7	59.5	20	63	9.8	7.2	1.76	5.63	69	81 1/2
General Tire[b]	19	568.5	6.6	11	[d]	1.2	[d]	0.27	2.43	24 1/2	26 1/8
Uniroyal	25	541.5	7.6	−7	[d]	1.4	[d]	0.24	−0.52	8	8 1/4
National Distillers	36	508.6	34.3	−8	−20	6.8	7.9	1.00	3.76	27 5/8	33 3/8
Upjohn	20	481.5	52.2	11	3	10.8	11.7	1.74	5.75	64 3/8	69

a After-tax income as percentage of sales. b Excludes major nonrecurring earnings: Mobil—$459 million in first-quarter 1980; Texaco—$402 million in first-quarter 1980; General Tire—$4.4 million charge in first-quarter 1981. c Earnings include nonrecurring items. d Deficit in first-quarter 1980. e Deficit.

STOCK MARKET DATA			
Stock price 12-Month low	Price-earnings ratio April 30	Annual indicated dividend April 30	Dividend yield, % of price
59	6	$6.00	8.8%
58 1/2	5	4.00	6.4
32 1/2	4	2.80	7.5
35 3/4	6	2.00	4.8
31 1/2	5	2.50	7.4
46	10	2.60	4.6
42 1/4	8	2.20	4.5
34	8	1.80	4.5
42 3/8	6	2.60	5.3
39	6	2.20	5.4
33 1/4	7	2.10	6.0
33 5/8	7	2.60	6.3
21 1/2	4	2.20	7.3
63 3/4	6	2.00	3.0
47 1/4	7	2.40	4.7
27 5/8	9	0.80	2.3
29 3/8	10	1.60	3.5
29 1/8	8	2.40	7.2
16 1/8	10	1.48	6.5
64 5/8	11	2.00	2.7
25 5/8	6	1.16	2.7
44 5/8	10	3.00	4.6
16 5/8	5	2.00	5.9
63	9	3.80	5.3
39 3/4	7	3.40	6.9
49	10	3.00	3.9
11 1/2	6	1.30	6.8
52 1/4	11	3.00	5.0
22 1/2	13	1.20	4.1
29 7/8	6	1.80	5.3
21	6	2.05	7.5
21 3/4	8	1.60	4.8
18 5/8	4	1.40	5.8
37 1/4	15	1.60	2.9
48 1/2	14	2.30	3.6
27 1/8	9	2.28	4.7
24 7/8	19	1.84	2.8
66	16	2.60	2.9
40 3/4	9	2.52	3.6
32 7/8	9	2.48	5.0
38 3/4	12	1.40	2.0
13 7/8	10	1.50	6.1
3 1/8	e	0	0
24 5/8	7	2.20	7.2
49 3/8	11	2.00	3.1

Petrochemical earnings plunge again

There's never much doubt from petrochemical earnings which part of the business cycle the industry is in. Right now, the cycle has to be close to a low point because petrochemical profits are still reeling. Whereas overall chemical earnings were down slightly in the first quarter from a year ago, petrochemical earnings lost more than half with just about everything going wrong. At some companies, petrochemicals ran in the red.

Decontrolled U.S. oil prices hit petrochemicals when petrochemicals were least able to pass along the added costs. Producers tried hard, pushing up a number of important product prices. But the increases were not enough and had to yield in many cases to market pressure for discounts. Producers obliged because plants were running at low rates, competing fuel outlets were soft, and export alternatives were weakening.

For six major U.S. oil companies supplying after-tax data, petrochemical earnings fell an average of 55% in the first quarter from a year ago. That's worse than the 36% drop for these companies in fourth-quarter 1980 and almost as bad as the 56% drop at the recessionary nadir in third-quarter 1980.

More oil companies than usual have spoken up this time about the petrochemical slump. At the largest, Exxon, chairman Clifton C. Garvin Jr. says that the company's U.S. petrochemical business sagged 7% in physical sales volume and lost 71% in earnings from a year ago. Abroad, physical sales volume was down 5% and earnings down 56%. Overall, earnings declined 62% and dollar sales 2%. With some understatement, Garvin concludes that Exxon's chemical operations have not recovered fully from worldwide recessionary conditions of 1980.

Mobil's chemical earnings fell 27% in the first quarter, the company says, because of a profit margin squeeze in the U.S. and lower petrochemical and plastics earnings in Europe.

Occidental Petroleum's chemical operations posted virtually no profit. The company blames lower sales and depressed profit margins in phosphate products and continued weakness in plastics.

And Gulf Oil reported a $4 million loss worldwide in chemicals in the first quarter after a $72 million profit a year ago. In the U.S., Gulf's chemical business lost $23 million against a $51 million profit in 1980.

More red ink flowed at Conoco, whose chemical operations lost $2.6 million in the first quarter after earning $25.5 million a year ago. Conoco lays the loss to lower profit margins for most major products, including chemicals from its big, new heavy-liquids cracking joint venture with Monsanto at Chocolate Bayou, Tex.

Cities Service and Shell Oil also had poor results. Cities Service's chemical operations lost $14.7 million in the first quarter. Shell's chemical earnings of $6 million are down from $22 million for the same period a year ago. This was mainly due, Shell says, to sluggish market conditions, particularly in the housing and automotive sectors, and higher raw material and other costs.

Details on the first-quarter damage to product volume come from Atlantic Richfield. Suffering a 79% chemical earnings decline, Arco was hit hardest in basic olefins. Its sales poundage in olefins dropped 25% from first-quarter 1980, and volume fell 3% in polymers. Arco's unit sales increased 1% in aromatics and 98% in oxygenated intermediates.

The situation is more hopeful for Standard Oil (Ind.). Standard considers its chemical business to be in a rebound from last year's third-quarter low point even though first-quarter earnings were still 34% lower than in first-quarter 1980. Standard points out that these earnings were 38% higher than in last year's fourth quarter. Some of Standard's firming may be due to its strong supplier position in raw materials for polyester, which has mounted a fair recovery so far this year. Standard says that profit margins in most of its product lines have remained relatively stable.

Since polyester outlets are frequently on the leading edge of the chemical business cycle, Standard's improving chemical results may hint of better times ahead for other companies' petrochemicals. But to go by past recoveries, petrochemicals won't step up profits for several more quarters.

	First-quarter after-tax earnings		
$ Millions	1981	1980	% change
Conoco	$ −2.6	$ 25.5	Deficit
Exxon	61.0	162.0	−62%
Mobil	26.0	36.0	−27
Shell Oil	6.0	22.0	−73
Standard Oil (Ind.)	39.4	59.2	−34
Texaco	22.4	30.1	−26
TOTAL	$152.2	$334.8	−55%

Canadian chemicals post so-so quarter

Earnings didn't keep pace with sales at two of Canada's four largest chemical firms, fell at another; Celanese only one to up profitability

First-quarter results from Canada's four largest publicly reporting chemical companies (C-I-L Inc., Celanese Canada, Du Pont Canada, and Union Carbide Canada) were nothing to brag about. Only Celanese could boast of improved profitability. C-I-L and Du Pont had healthy sales increases but their earnings increases didn't keep pace. Sales were actually down at Carbide, where profits were off more than a third.

Combined sales for the four firms came to almost $859 million (Canadian), 12% higher than in first-quarter 1980. With inflation factored in, that's hardly any increase at all. Combined net income for the period amounted to $46.7 million, 8% less than in the year-earlier period. Profitability, in terms of return on sales, averaged 5.4% for the four companies, compared to 6.6% a year earlier.

C-I-L recorded sales of about $271 million, 19% higher than in the first quarter of 1980. However, net income of $11.1 million represented an increase of only 17% over the like period in 1980. Return on sales amounted to 4.1%, down slightly from 4.2% in 1980.

Chairman and chief executive officer W. J. Mandry notes that C-I-L sales were up in all the company's businesses, with significant gains in agricultural and industrial chemicals, explosives, and mining equipment. But earnings were held down by increased costs, particularly higher natural gas feedstock costs for agricultural chemicals and plastics. "Only the industrial chemicals, explosives, and mining equipment businesses achieved meaningful improvements in operating income over the first quarter of 1980," Mandry says. He adds that second-quarter results will depend largely on the fertilizer business.

Celanese Canada sales came to nearly $105 million, only about 6% higher than in first-quarter 1980. Net income totaled $6.2 million, up 18% from the 1980 period. The firm's profit margin rose accordingly, to 5.9%, compared to 5.3% in the first quarter of 1980.

According to Celanese president Richard M. Clarke, the increase in earnings was largely the result of cost-cutting and energy-saving programs put into effect during the past several years. He also notes "signs of renewing strength" in Celanese's textile-related businesses, adding that he expects further growth in both sales and earnings from those divisions.

Sales at Du Pont Canada amounted to a little more than $283 million, an increase of almost 21% from the first quarter of 1980. Like C-I-L, Du Pont couldn't translate its sales gain into a corresponding increase in earnings. Net income for the period was $14.7 million, a 16% increase from first-quarter 1980. Return on sales dropped to 5.2%, compared to 5.4% in the like 1980 period.

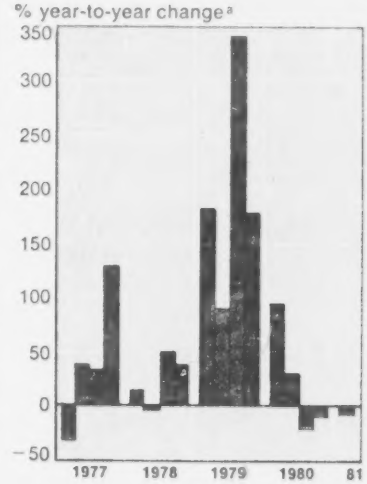
Du Pont notes significant gains in first-quarter sales of nylon apparel and carpet yarns and nylon carpet fibers. However, demand for packaging materials and woven polyolefin fabrics was down, compared to last year. Exports of manufactured products rose 24% from year-earlier levels, the company says.

It was, as noted, a rather poor first quarter for Union Carbide Canada. Sales fell to about $200 million, about 1% lower than in the first quarter of 1980, and representing a substantial decline in real volume. Net income dropped to $14.7 million, about 36% less than in the year-earlier period. Return on sales fell to 7.3%, compared to 11.4% in the like quarter in 1980. Even so, Carbide was, as usual, the most profitable of the four firms.

Carbide president John S. Dewar notes that product prices couldn't keep up with increases in raw material costs during the quarter. He adds, however, that the decline was "largely a delayed reaction to the generally sluggish nature of the economy" in 1980. He explains that Carbide is basically a supplier of materials to other industries; when the economy slows down, there generally is a time lag of about six months before cutbacks in those industries affect Carbide's results.

Ward Worthy, Chicago

Combined earnings drop 8% in first quarter



a After-tax earnings of four largest publicly reporting Canadian chemical companies—C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada

Union Carbide Canada earnings drop 36%

	FIRST-QUARTER 1981					
$ Millions (Canadian)	Net sales	Change from 1980	Net income	Change from 1980	Profit margins[a] 1981	1980
C-I-L Inc.	$270.6	19%	$11.1	17%	4.1%	4.2%
Celanese Canada	104.9	6	6.2	18	5.9	5.3
Du Pont Canada	283.1	21	14.7	16	5.2	5.4
Union Carbide Canada	200.2	−1	14.7	−36	7.3	11.4
TOTAL	$858.8	12%	$46.7	−8%	5.4%	6.6%

a Net income as percentage of sales.

Many forces shaping strategic minerals policy

Conflicts over developing seabed resources as well as public lands for mining complicate goal of reducing U.S. dependence on imports

Lois R. Ember
C&EN, Washington

In a surrealistic stab at halting the Reagan Administration's avowed intent of opening up more federal land to exploration and mining, the Sierra Club Legal Defense Fund, on behalf of 12 grizzly bears, sued the federal government to protect the bears' Montana wilderness habitat from the miner's pick. The grizzlies are the most recent pawns in what is shaping up to be a long-running battle pitting conservationists against the mining industry's most vocal advocate, Interior Secretary James G. Watt. The issue is strategic nonfuel minerals, but the arguments are couched in terms of environmental protection, economic stability, and national security.

For instance, in a modern update of the Leninist doctrine aimed at destroying capitalism, the Soviet Union is accused of waging a "resource war" to deprive the West of such strategic materials as nonfuel minerals, which it needs to fuel its military and industrial machines. As Rep. James D. Santini (D.-Nev.), chairman of the House Mines & Mining Subcommittee, explained at hearings he held last year, in the nonconventional war the U.S.S.R. now is waging the acquisition of vital raw materials by noneconomic means is tightly woven into the design of its global political strategies.

"As a result of a rapidly deteriorating mineral resource position," Santini intoned, "the Soviet Union has moved into the international resource arena armed with a strategy of confrontation that extends beyond economic competition, but which falls just short of conventional military conflict." Santini's leadoff witness, Alexander M. Haig Jr., then president of United Technologies Corp. and now Secretary of State, anointed Santini's statement. Yes, he said, the resource war had arrived. Just witness stepped-up Soviet and Soviet-proxy activity in developing countries, the repository for many vital materials.

In the Heritage Foundation's "Mandate for Leadership"—the Reagan Administration's blueprint for governing—Robert L. Terrell writes: "America is now 50% or more dependent on foreign sources for 24 of the 32 strategic and critical minerals essential to our national survival." Many of these imports come from potentially volatile, developing-country sources—Zaire, Zambia, Zimbabwe, and the Republic of South Africa—as well as the Soviet Union.

To make the U.S. less vulnerable to foreign imports, Terrell advocates a booming domestic mining and minerals processing industry. However, for that to occur, the anemic $25 billion minerals sector of the U.S. economy must be revitalized by government action. Terrell's suggested remedies: increased access to mineral-rich, federal lands; relaxation of environmental and health and safety laws; more favorable tax laws; and government purchases and/or guaranteed prices for certain metals such as cobalt and titanium. Terrell also calls for a foreign policy favorable to those countries that are reliable suppliers of vital materials.

With the assistance of Congressional allies such as Santini, the defense-minded Reagan Administration is starting to make good on campaign promises to wean the nation from its dependence on foreign sources of strategic materials.

At his confirmation hearings, Watt pledged to open up vast areas of public lands now off limits to mineral exploration. In March he began to make good his pledge. Through administrative changes, he proposed to ease controls on all public land now being considered for addition to the federal wilderness system. The changes would make it easier for companies holding mining claims issued before Congress passed the 1976 Federal Land Policy & Management Act to develop these claims.

Also in March, President Reagan announced that a Carter initiative to restock the U.S. inventory of strategic materials would be funded in fiscal 1981. For the first time in 20 years, the government would begin to replenish its national defense stockpile of some 93 materials (80 of them minerals) deemed necessary to fuel the military and industrial machines in the event of a three-year war.

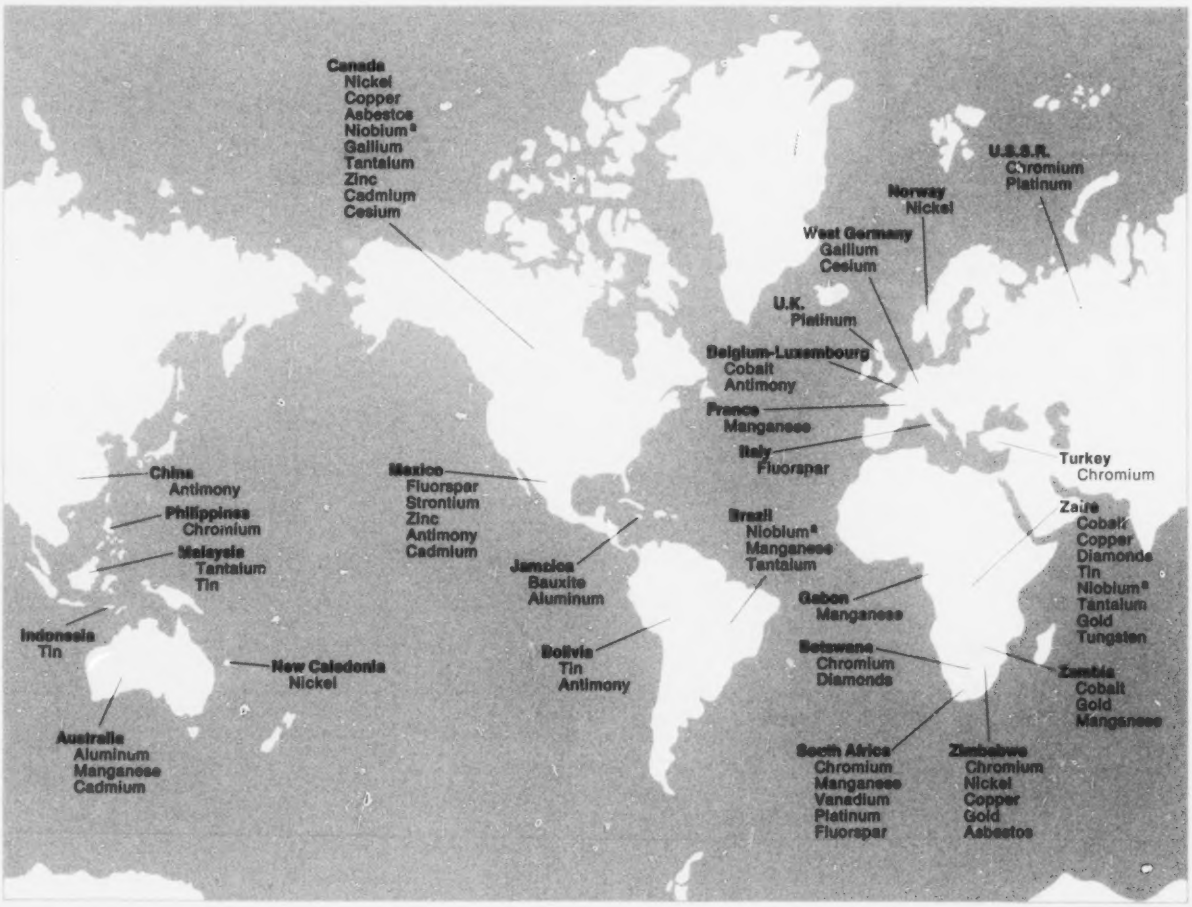
To "decrease this nation's vulnerability," President Reagan announced that the government would buy $100 million worth of strategic materials, beginning with 1.2 million lb of cobalt, a metal used in the superalloys needed for jet engines. Although the government listed 15 other items it would like to buy in the future, no funds have been allocated for that purpose. To meet current stockpile goals, some $12 billion would have to be spent. Current plans are to finance stockpile purchases through the sale of other government-held "surplus" materials, including silver and tin.

Again in March, at the request of U.S. mining companies, the Reagan Administration decided to reassess the Carter Administration's position on the Law of the Sea Treaty, which was expected to be signed this fall after seven years of negotiations among 150 nations. The Reagan review is an attempt to win seabed mining provisions more favorable to U.S. companies.

These actions and the formation of a Cabinet council on resources and environment chaired by Interior Secretary Watt indicate the Administration's intent to make a national minerals policy a top priority. Still, despite the administrative steps Watt may take to open up federal land to mining, and despite Rep. Santini's "National Mineral Security Act," which would subsidize the mining industry, the Administration is likely to move slowly on meeting industry's demands. To do otherwise could result in politically damaging Congressional battles over environmental and federal-spending issues.

The American Mining Congress, backed by the U.S. Chamber of Commerce, claims that lack of access to mineral-rich public lands, unfavorable tax laws, and costly environmental regulations have resulted in a stagnating domestic mining industry and a declining minerals processing

U.S. gets its strategic materials from some 25 countries



a Traded as columbium. **Note:** U.S. imports 50% or more of its need for these materials.

industry. As a consequence, the U.S. has inadequate stockpiles of strategic materials and is gravely dependent on countries that are economically, socially, or politically unstable, or are at the far end of shipping lanes vulnerable to Soviet interdiction.

For example, cobalt needed for the manufacture of jet engines and guided missile controls is imported from Zaire, Zambia, and Australia. In 1978, shortly after the Soviet Union made large purchases of cobalt, its proxy Angola sent Katangese troops into Zaire's cobalt-rich Shaba province. The temporary cutoff propelled cobalt prices skyward.

Then there is always the possibility that mineral-rich developing countries could form cartels to limit availability and thereby drive up the prices of strategic minerals. However, Hans Landsberg, a minerals expert at Resources for the Future, a Washington, D.C., "think tank," discounts that possibility. Stable countries such as Australia, Canada, and Mexico, which are major exporters of strategic minerals, are not likely to form cartels, and the less-stable nations of central and south Africa are too poor to do without the income from minerals exports, Landsberg says.

Still, the Soviet Union is able to influence the mineral policies of these African countries through military arms and economic support, some hawks in the mining industry and in government assert. And, they claim, the Soviet Union can also carry on its resource war against the U.S. by withholding its supplies of chromium and manganese, and by purchasing on the open market supplies of metals such as cobalt, thus depriving western industrialized countries of these metals.

Understandably, environmental groups and Interior Secretary Watt—self-proclaimed "friend" of the mining industry—seek different solutions to low minerals inventories. Sierra Club's Washington representative, Tim Mahoney, says that for the short term the U.S. can continue to maintain good relations with central and south African nations, continue to import vital minerals, and make modest additions to the strategic stockpile. For the long term, the U.S. can develop financial and tax incentives to encourage conservation and recycling of strategic metals, Mahoney says. Watt says, "The best answer to minerals availability is domestic production."

As friend "of the minerals industry in the court of federal policy making," Watt has vowed to use the provisions of the National Materials & Minerals Policy, Research & Development Act of 1980, and its predecessor, the Mining & Minerals Policy Act of 1970, "to foster and encourage ' a private U.S. minerals industry, and to shape a national strategic minerals policy.

However, with its many demands,

These imported strategic minerals drive military, industrial machine

	Chromium	Cobalt	Manganese
Uses	Stainless steel, especially for parts exposed to high temperatures, corrosive gases	High-temperature alloys in jet engines, magnets, cement mixtures of tungsten chloride for drilling bits, catalysts	Steelmaking (as ferromanganese)
% of need imported by U.S.	91%	93%	97%
Sources (% of U.S. imports supplied)	Chromite: Republic of South Africa (40%) Philippines (15%) U.S.S.R. (16%) Turkey (10%) Ferrochromium: Republic of South Africa (62%) Yugoslavia (11%) Zimbabwe (9%) Japan (5%)	Zaire (42%) Belgium-Luxembourg (16%) Zambia (13%) Finland (6%)	Manganese ore: Gabon (44%) Brazil (24%) Australia (9%) Republic of South Africa (9%) Ferromanganese: Republic of South Africa (38%) France (22%) Japan (7%)
Stable sources	Finland Philippines	Australia Canada Finland New Caledonia	Australia Brazil France
Price	South African high-iron chromite: $51–$55/metric ton; ferrochromium prices higher	$25/lb	—
Amount recycled	9% of total demand	600 tons or 8% of reported estimated consumption	Not significant
Stockpile status[b]	Chromite, all grades: Goal, 4725 tt Total inventory, 2590 tt Chromium ferroalloys: Goal, 350 tt Total Inventory, 759 tt Chromium: Goal, 20 tt Total inventory, 4 tt	Goal, 42,700 t Total inventory, 20,402 t	Metallurgical ore: Goal, 2700 tt Total inventory, 2410 tt Ferromanganese, high carbon: Goal, 439 tt Total inventory, 600 tt
Substitutes	Nickel, zinc, or cadmium for corrosion protection; nickel, cobalt, molybdenum, vanadium for alloying iron and steel	Nickel, for most uses with some loss of effectiveness	No satisfactory substitute
Comment	Most of U.S. resources are in Stillwater complex, Montana, and beach sands of Oregon	U.S. domestic mine production stopped end of 1979	U.S.S.R. and Republic of South Africa have more than 80% of world-identified resources

a Produced from rutile. b tt = thousands of tons, t = tons, tto = thousands of troy ounces, tp = thousands of pounds. **Source:** Bureau of Mines, Department of the Interior

the mining industry is not making it easy for an administration elected on a platform promoting federal spending cutbacks and free-market enterprise. In addition to expanded investment credits, special accelerated depreciation for investment in mining production and tax-exempt financing of antipollution equipment, mining companies also have asked for greater access to explore and mine public lands, and for some type of price support for hard-rock minerals.

Much to the chagrin of some environmentalists, Watt has declared his intent to use his administrative powers and to support legislative initiatives to open up scenic federal lands to oil and gas drilling, lumbering, and hard-rock minerals mining. Yet the Administration has sent no legislation to Congress, and Watt has not taken administrative action to release to multiple use the 150 million acres managed by the Bureau of Land Management that, after study, have been declared unsuitable for wilderness designation.

Even in wilderness areas, under provisions of a 1964 law, mining companies can stake claims until Dec. 31, 1983, and mine in those areas so long as their wilderness characteristics are not violated. Watt has indicated that he would like that deadline extended, possibly until 2000.

Shaping a minerals policy is made difficult by competing national needs, jostling among various constituencies for access to public lands, and turf protection among the various federal agencies with oversight over segments of such a policy.

The Administration is developing a foreign policy favoring countries that are reliable suppliers of strategic minerals. And it favors extending for five years the Defense Production Act, which expires in September. Title III of the act could be used to encourage U.S. minerals production and processing by providing government loans, loan guarantees, purchase commitments, guaranteed production

Platinum-group metals	Titanium: As semiprocessed sponge metal[a]	Titanium: As titanium dioxide	Vanadium
Catalysts in automobile exhaust antipollution devices, and in chemical and petroleum refining industries	Jet engines, space and missile applications; chemical processing industry; steel and other alloys	Nontoxic white paint	Alloying agent for iron and steel, catalyst for production of sulfuric acid; important in production of titanium alloys
87%	100%	14%	15%
Republic of South Africa (53%) U.S.S.R. (22%) U.K. (12%)	Australia (84%) India (5%)	West Germany (35%) Canada (16%) U.K. (15%) Belgium (7%)	Republic of South Africa (55%) Chile (23%) Canada (5%)
Canada	Australia	Present sources stable	Domestic supplies can supply domestic needs, though at a price disadvantage over imports
Platinum: around $450/oz Palladium: around $300/oz	63 cents/lb	—	$3.54/lb
About 16% of sales to industry	No recycling of rutile; 20,100 tons of new scrap titanium recycled	No recycling of titanium dioxide	Not significant
Platinum: Goal, 1310 tto Total inventory, 453 tto Palladium: Goal, 3000 tto Total inventory, 1255 tto Iridium: Goal, 98 tto Total inventory, 17 tto	Specification sponge metal: Goal, 195,000 t Total inventory, 21,465 t Rutile: Goal, 106,000 t Total inventory, 39,000 t	—	Vanadium pentoxide: Goal, 15,400 tp Total inventory, 1082 tp Ferrovanadium: Goal, 2000 tp Total inventory, 0
Gold, silver, tungsten in electrical/electronic uses; rare-earth metals, nickel, vanadium, titanium in catalytic uses	For aircraft and space use, no substitute for titanium; for industrial uses, high-nickel steel and superalloy metals may be substituted		For alloying purposes, niobium, molybdenum, manganese; platinum as a catalyst in some chemical processes
Exploration continues in the Stillwater complex in Montana	Titanium can be produced from domestic sources of ilmenite, if necessary		Last year, vanadium consumption declined because of lower activity in the steel industry

levels, or guaranteed prices to companies.

The Federal Emergency Management Agency, which sets policy for the strategic materials stockpile, is "exploring projects" with mining companies to expand U.S. production of cobalt, titanium, refractory bauxite, and guayule. Noranda Mining, a subsidiary of Noranda Mines Ltd. of Toronto, Ont., has asked FEMA for a government-guaranteed price of $22 per lb for cobalt to justify continued development of its claims in the River of No Return Wilderness area of Idaho. Since 1977, cobalt prices have leapfrogged from about $6.00 per lb to $25 per lb last year.

Use of Title III, says Sierra Club's Mahoney, would "just make marginal deposits of minerals more profitable to mine." And, he adds: "Not only would we be giving away public lands to the mining companies, but we would be subsidizing their production costs."

At this point, it's not certain just how much U.S. production could be stimulated even if the Defense Production Act was used "to subsidize" critical materials production, as Interior's deputy secretary for energy and minerals W. Perry Pendleton says it could be used. Even after the Carter Administration spent three years and $3.5 million to survey strategic minerals deposits, there is still no precise estimate of the nation's potential mineral resources. That's why Keith Knoblock of the American Mining Congress says mining companies need access to public lands. "There is no way to tell what minerals are out there until you put in drill holes," he asserts. But Mahoney contends that virtually all laws, including the Wilderness Act, give mining concerns "reasonable access."

Morgan of the Bureau of Mines, however, agrees with Knoblock. "It is always possible that high-quality deposits of minerals might be found. Certainly Alaska has been little ex-

plored for strategic minerals," he says. As for known reserves in the lower 48 states, Morgan says that cobalt probably would be mined in Idaho if the government guaranteed companies a fixed price, and titanium, though not available to any great extent on public lands, could be produced in the U.S. if smelting facilities were available. Platinum is being prospected for in the Stillwater complex in Montana, but there are no known economically minable deposits of manganese or chromium, he says.

Although the American Mining Congress cites old Interior Department statistics claiming that 50 to 70% of all public lands are partially or entirely closed to mineral exploration and mining, Mahoney claims that only 25% of all public land is excluded from mining. Only national parks, defense reservations, and special-purpose enclaves are barred to mining. Even wilderness areas are not immune to mining claims until the end of 1983, Mahoney points out. Moreover, he says, "just the barest whiff of minerals pulls land out of the wilderness classification," thus lessening the restrictions on mining activities on that land.

Hugh Riecken, director of BLM's wilderness review, says that of the 24 million acres still being studied for their wilderness potential, 15.5 million acres may be recommended as suitable for mineral surveys by the U.S. Geological Survey and the Bureau of Mines. This number is only an estimate, and is no indication of the number of acres containing economically recoverable mineral deposits. BLM's wilderness review by law must be completed by 1991.

Until the review is completed, the American Mining Congress, the American Institute of Iron & Steel, the U.S. Chamber of Commerce, and numerous mining companies are strongly backing Rep. Santini's introduction of the "National Minerals Security Act." His four-pronged bill would:

- Give the Interior Secretary the means to release to exploration and mining public lands, and require the secretary to inventory domestic strategic minerals resources.
- Amend tax laws to assist the mining industry in making the capital investments necessary to locate, develop, and produce vital minerals.
- Establish a White House-level council to coordinate the development of a national minerals policy.
- Create a revolving fund for the sale and purchase of strategic minerals.

It currently is cheaper to import strategic minerals than to recover low-grade domestic ores. Just how administrative measures and legislative fiat will change the economics and spur U.S. production remains to be seen. But Sierra Club Legal Defense Fund attorney Bill Curtiss asks: "Does it make sense to open U.S. resources of strategic minerals to foreign developers and to export? And if it is true that relying on foreign sources is a security risk, why is it reasonable to mine and consume all of our own resources as rapidly as we can?"

Good questions. However, some argue that the billions of tons of nickel, cobalt, and manganese in nodules lying on the seafloor just waiting to be plucked are, in fact, insurance against the time when the U.S. hard-rock mineral resources are mined out, and are powerful weapons against the Soviet Union's resource war.

Although five major industrial consortia stand ready to mine the ocean floor, they are not likely to do so without an international agreement. And early last March, the glimmer of such a treaty dimmed when President Reagan called for a full-scale review of the Law of the Sea Treaty and instructed his new negotiating team "to ensure that the negotiations don't end at the present session."

Four of the five major consortia are headed by U.S. companies, which are now governed by the 1980 "Deep Seabed Hard Mineral Resources Act." That act calls for commercial mining to begin in 1988, but most importantly, it calls on the Administration to seek inclusion in the Law of the Sea Treaty of "grandfather" rights that will allow companies licensed under the U.S. law to continue economic operations under the international agreement. The current draft treaty, now under interagency review, has no grandfather provisions.

Alarmed that the draft treaty would obstruct access of U.S. mining companies to seabed riches, mining companies, some members of Congress, Interior Secretary Watt, and officials from the Energy and Treasury departments as well as the National Security Council pressured for review. According to Theodore S. Wilkinson, deputy director of the State Department's Law of the Sea Office, the review will determine whether "U.S. basic interests are satisfactorily represented in the draft treaty." However, the review will have to balance the complaints of the mining companies against strategic interest in open sea lanes vital to naval maneuvers. The draft treaty provides for open sea lanes.

Mining companies called for the review for many reasons. But their primary concerns are for security of access to sites on the seafloor that they have prospected, explored, and perhaps even begun to mine, and for security of tenure that these sites would still be theirs when the treaty is entered into in the mid-1980's. The draft treaty doesn't grant these as-

Cobalt: U.S. is dependent but not vulnerable to imports

Although there are about 160,000 tons of known deposits of cobalt in the U.S., the metal was last mined in this country a decade ago. It simply is much cheaper to buy cobalt on the world market. And for that reason, 93% of all cobalt consumed in the U.S. is imported, mainly from central and south African countries subject to internal conflicts, guerrilla wars, or foreign invasions. Their instability makes U.S. supplies susceptible to interruption. Because cobalt is vital to U.S. defense and civilian economy, any cutoff, the argument goes, weakens national security.

The Soviet Union, on the other hand, is nearly self-sufficient in cobalt and 92 other materials the U.S. classifies as strategic. However, shortages are soon expected for some of these materials, so being "good capitalists" the Soviets have begun to compete with the West for strategic minerals in Africa. By so doing, they fill their own coffers while at the same time preserve their own resources and deprive the West of crucial materials. It's called a resource war.

James Thomason, a defense analyst with the Center for Naval Analysis and a man who marches to a different cadence than present-day Cassandras crying "resource war" and "mineral squeeze," argues that "Soviet aggression should be firmly opposed," but it is "simplistic to equate U.S. vulnerability to U.S. import reliance," especially for cobalt.

Thomason argues that even if African (and Australian and New Caledonian) sources of cobalt were severed completely, the U.S. still would be able to run its war machine during a protracted conflict on its own supplies—both from stockpile reserves and in-ground resources—and from Canadian imports. And if really hard-pressed, U.S. and Canadian nickel could be substituted for

cobalt for most uses. None of this would be cheap, but the U.S. would not be vulnerable to Soviet meddling. Furthermore, sometime before the turn of the century, Thomason reminds us, the U.S. probably will be extracting unlimited quantities of cobalt from manganese nodules mined from the Pacific Ocean floor.

Why, Thomason asks, is the U.S. planning to buy 1.2 million lb of cobalt for its national defense stockpile when current inventory (20,000 tons) is already more than twice the present defense and civilian use rate for the metal? He would like to see stockpile goals "pegged to improved measures of import cutoff vulnerability.

"The most appropriate framework for setting stockpile policy," Thomason says, "is a weighted version of the cost of loss." That is, a quantitative measure of the cost of loss from an import cutoff multiplied by the likelihood that a cutoff will occur.

Any valid measure of vulnerability, he continues, should take into account the availability of substitute metals, and the so-called surge production capability of U.S. producers and stable foreign producers (Canada). Surge production capability is the lag time before production could meet demand, or a significant portion of demand, so that existing stockpiles could be stretched over longer periods of time.

Before the U.S. completely falls prey to those strident mineral squeezers who argue that the Soviets will bring the U.S. to its knees by squeezing it dry of vital minerals such as cobalt, Thomason would like to see rational debate in Congress on the proper model to use to set stockpile policy. Today the U.S. is operating on the "myth of the complex machine," Thomason chuckles. "If you remove the battery from a transistor radio, the radio stops playing. If you cut off foreign sources of cobalt, our military-industrial machine grinds to a halt. Malarkey!"

surances. Without them the companies will not be able to capitalize their risky and costly ventures, says Charles Cook, vice president of the American Mining Congress.

Another major concern of the mining companies is that they have sufficient production authorization to earn respectable profits. However, under the draft treaty, a mining company wouldn't know what its production quota was until after it made the substantial investments needed to present its proposal to obtain a seabed mining site.

Moreover, Jeffrey K. Amsbaugh, president of Deepsea Ventures, a Virginia company that is a member of Ocean Mining Associates consortium, says there are production controls in the treaty that limit the amount of nodules that can be mined, and that limit is based on the "growth of demand for nickel in the world."

In addition to concern about access, tenure, and production quotas, some U.S. mining companies are reluctant to turn over their technology to a United Nations company called the Enterprise that would be set up under the draft treaty. Under current terms, to obtain mining sites consortia would have to transfer technology to the Enterprise, which also would mine the seabeds. Any profits made by the Enterprise would be divided among developing nations. Amsbaugh says that some companies "from whom we buy technology would be unwilling to sell us this technology if the current Law of the Sea Treaty" is ratified.

Can the current draft document be modified to satisfy the complaints of the mining companies? Wilkinson says that Carter Administration negotiators (led by George A. Aldrich, whom Reagan replaced with James L. Malone) claim that "certain refinements to the treaty are necessary, but the basis for these refinements exists." Amsbaugh says, "This treaty is so bad that it can't be patched."

"No company will invest in deep-sea mining ventures if the Law of the Sea Treaty is not changed to assure security of access and tenure," Cook of the American Mining Congress asserts.

The U.S. and West Germany already have national laws governing seabed mining. Belgium, France, the U.K., Italy, and India are developing similar legislation. Amsbaugh envisions harmonizing these national laws into a minitreaty that will allow the participating countries to proceed with their mining ventures whether or not a UN-sponsored international agreement is ratified.

The Administration's review will not be completed until fall. It is quite possible that the strategic need for rights of passage in sea lanes will supersede mining company concerns, and the Administration will decide to negotiate completion of the draft document. Then the mining groups will have to decide whether to proceed to commercial development.

The prospect for profit must be a powerful tug. Littering the floor of the Pacific Ocean are vast reserves of potato-size nodules containing manganese, nickel, copper, cobalt, and some vanadium and molybdenum. If even a small percentage of the nodules are recoverable, the world's reserves of these vital minerals could double or triple. And, according to researchers at the University of Manchester, mining companies could earn profits of up to 112%, depending on how many minerals a project is designed to extract. For now, though, even for the oldest and most active consortium, Ocean Mining Associates headed by U.S. Steel, seabed mining is at best a marginal venture.

Certainly, Congress' clamor for economic recovery in the U.S. minerals sector and for assured national security, and the Reagan Administration's striving for military might are driving forces behind an eventual national minerals policy. Still, even without such a policy, these rather exotic strategic minerals are already sought-after commodities. Respected security houses are now trading them, and oil companies, bloated from oil decontrol wealth, are snatching up mining companies.

Unfortunately, as Robert F. May of the Forest Service points out, the "best minerals prospects are likely to be in areas that are geologically disturbed"; that is, craggy or mountainous—in short, picturesque.

There certainly is beauty in the grizzly bears' Montana habitat, and there probably are minerals there, too. In this instance, the federal judge hearing the case ruled against the grizzlies and for the government and Asarco, which intervened. The judge ruled that the government's data amply supported its decision to allow Asarco to prospect for copper and silver in the bears' home, the Cabinet Mountains Wilderness area of Montana. The problem is that the judge ruled only on government evidence, Bill Curtiss of the Sierra Club Legal Defense Fund says. The judge overruled the need for an environmental impact statement, and thereby kept "other interested groups from commenting on the factual accuracy of the government's record," Curtiss contends.

He argues that the banner of economic stability and national security should not be used to cover the rape of federal lands. To assure that that doesn't occur, all interested parties—the Interior Department and Secretary Watt, mining companies, and environmentalists—should be allowed to comment on the use of public land. Unfortunately, that wasn't allowed in the grizzly bear case, Curtiss says. □

NOTE

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Chemical & Engineering NEWS

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Gasoline to trigger aromatics shortage

Demand for high-octane, low-lead gasoline will dominate production and pricing of aromatics, putting squeeze on petrochemical industry

Gasoline will dictate how much aromatics will be available for the petrochemical industry in the 1980's and how much the industry will pay for them.

And with the U.S. gasoline market moving relentlessly toward the regular and premium unleaded grades, aromatics figure to give chemical purchasing agents more than their share of headaches in the years ahead.

Certainly Eugene J. Debreczeni, vice president of DeWitt & Co. (Houston), isn't optimistic about the outlook for aromatics. He told a recent joint meeting of the Chemical Marketing Research Association and the European Chemical Marketing Research Association in New York City that, as leaded gasoline gets squeezed out of the market, the industry will experience severe shortages in aromatics supply.

Debreczeni also believes that, as octane requirements increase, the value of aromatics will rise faster than any other refinery product. It will, that is, unless the government allows refiners to increase octane by some alternative other than increasing the aromatics content of gasoline.

The simple solution would be to put lead additives into gasoline again, but that isn't likely to happen. Other available high-octane blendstocks, such as methyl *tert*-butyl ether (MTBE), ethanol, and methanol, will help ease the burden.

But that burden is enormous. By 1990, Debreczeni estimates that total aromatics demand will hit 35.5 billion gal, a hefty 5.5 billion gal higher than it was last year. Almost 80% of that increase will be earmarked for the gasoline pool.

The irony of the unfolding aromatics situation is that U.S. gasoline consumption will decline during the eighties. Demand, which peaked at about 114 billion gal per year in 1978, already has dropped substantially. It was only 101 billion gal last year. And by 1990, annual gasoline consumption in the U.S. will be down to 83 billion gal, says Debreczeni.

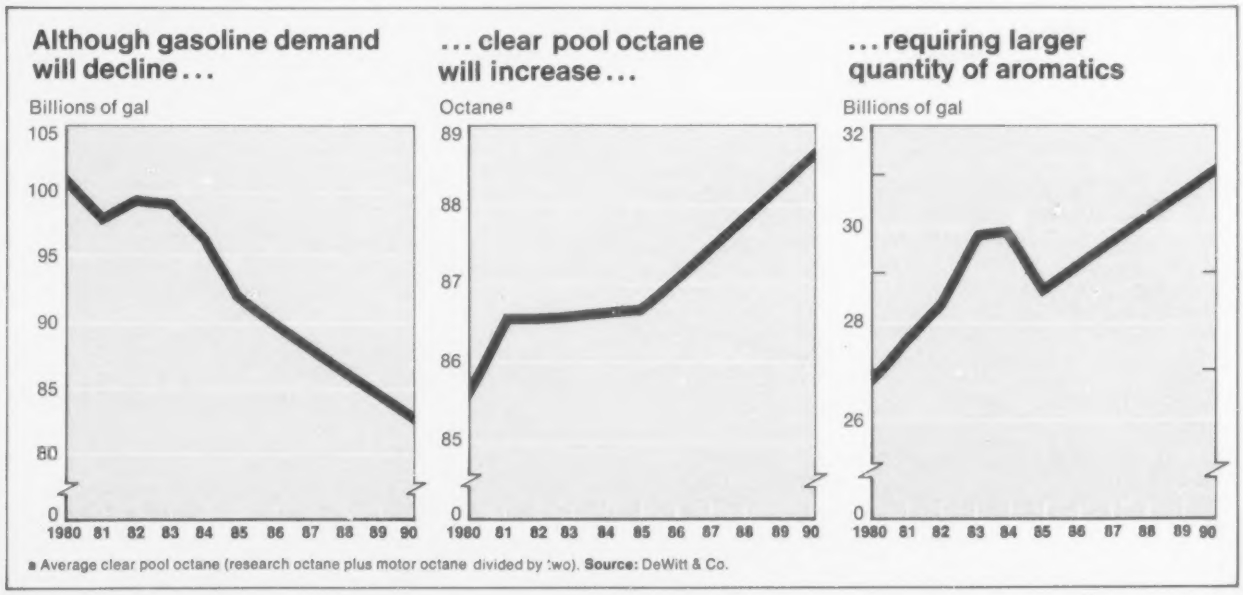
For aromatics, the hitch is that unleaded gasoline will have replaced virtually all leaded gasoline by 1990. Unleaded premium grades will total 40% of the market, he says.

This will bring about significant changes in clear pool octane requirements (octane of the gasoline pool before adding tetraethyllead). This year, the average octane of the clear pool will be 86.6, two points higher than it was in 1978. By 1990, says Debreczeni, clear pool octane will go up another 2.1 points to 88.7.

This octane trend is important because it will require huge volumes of aromatics (or aromatics precursors such as catalytic reformate) to satisfy it. To increase octane only one point, about 4 billion gal more toluene and/or xylenes have to be added to the total pool. Or about 7.5 billion gal of 100 octane reformate could be used.

Debreczeni puts these numbers in perspective for the petrochemical industry by pointing out that, in 1981, total demand for benzene, toluene, and xylenes will be about 3.4 billion gal. That 7.5 billion gal of reformate contains 230 million gal of benzene, 1.3 billion gal of toluene, and 1.35 billion gal of xylenes. Some of these aromatics, he says, could be used for petrochemicals.

Last year, 26.9 billion gal of aromatics were consumed as gasoline. That includes the aromatics content of catalytic reformate, cat-cracked gasoline, other refinery sources, and the toluene and xylenes that were extracted from reformates then



[a] Average clear pool octane (research octane plus motor octane divided by two). **Source:** DeWitt & Co.

Outlook for aromatics in the eighties

Styrene will dominate benzene demand . . .

Millions of gal	1980	1982	1985	1990
Detergent alkylate	41	48	52	60
Aniline	80	91	90	110
Cumene-phenol	288	365	360	590
Cyclohexane	220	295	300	350
Ethylbenzene-styrene	790	910	920	1220
Maleic anhydride	42	52	50	50
Others	46	75	68	70
Total domestic	1507	1836	1840	2450
Export	12	15	10	—
TOTAL	1519	1851	1850	2450

. . . reformers to remain top benzene source

	Nameplate capacity (millions of gal) Announced			Estimated
	1980	1981	1985	1990
Reformers	994	1014	1104	1164
Hydrodealkylation/ disproportionation	733	747	747	820
Pyrolysis gas	634	758	758	818
Coal	159	159	159	159
TOTAL	2520	2678	2768	2961

Isomers use will spur xylenes growth . . .

Millions of gal	1980	1982	1985	1990
Isomers	880	950	910	1080
Solvents	115	105	90	100
Other	45	55	50	70
Total domestic	1040	1110	1050	1250
Exports	78	70	75	50
TOTAL	1118	1180	1125	1300

. . . with excess going to the gasoline pool

Millions of gal	1980	1982	1985	1990
Domestic production	1200	1240	1250	1400
Imports	57	60	70	75
Total supply	1257	1300	1320	1475
Available for gasoline	139	120	195	175

Source: DeWitt & Co.

Toluene demand to grow 5% annually . . .

Millions of gal	1980	1982	1985	1990
Benzene	465	675	565	820
Benzoic acid, benzyl chloride	20	22	22	30
Solvents	115	110	100	75
Other chemicals	55	62	62	95
Total domestic	655	869	749	1020
Exports	53	100	105	135
TOTAL	708	969	854	1155

. . . leaving less available for gasoline

Millions of gal	1980	1982	1985	1990
Domestic production	1550	1640	1500	1700
Imports	82	80	100	100
Total supply	1632	1720	1600	1800
Available for gasoline	924	751	746	645

blended back into the gasoline pool. This year, the pool will require an additional billion gallons of aromatics, primarily because the lead content is dropping from 0.8 gram per gal to 0.5 gram. By 1985, still another billion gallons of aromatics will be needed. And, between 1985 and 1990, the incremental requirement for aromatics in gasoline could be as high as 2.5 billion gal.

High-octane blendstocks, such as MTBE and the alcohols, will help. But Debreczeni warns that catalytic reformers will have to carry the burden.

Thus, the petrochemical industry may be hard-pressed to meet its own aromatics demand, which Debreczeni says will require 1.2 billion gal more aromatics in 1990 than last year.

Benzene demand, for instance, will increase roughly 60%, or about 930 million gal, during the eighties. However, this average 4.9% annual growth won't be smooth throughout the decade.

Debreczeni forecasts a slow but steady growth in benzene demand through 1984. Somewhere between 1984 and 1986, however, he anticipates a recession that could be as severe as the one in the early 1970's, perhaps even worse. As a result, he believes that benzene demand will drop around 1985 before it resumes growing again.

Whatever the growth pattern, ethylbenzene-styrene will dominate the benzene market throughout the decade. Although it won't be the fastest-growing end use, ethylbenzene-styrene will continue to account for about 50% of total demand.

To satisfy this increasing benzene demand, new capacity will be needed and producers will have to plan on higher operating rates. Announced expansions will raise capacity from last year's 2.5 billion gal to 2.77 billion gal in 1985. Debreczeni estimates that by 1990, capacity will reach 2.86 billion gal, including at least one 60 million gal-per-year extraction plant from reformate, two more 40 million gal Hydeal units, and 60 million gal of additional extraction capacity from pyrolysis gasoline.

Along with the new capacity, operating rates will increase, from a lowly 60% last year to about 86% in 1990.

Toluene demand will increase at a 5% annual rate during the eighties, pushing 1990 volume to 1.15 billion gal. Of all the toluene markets, only solvents are expected to decline. Exports, which were very low last year, will more than double to 135 million gal by 1990.

Toluene supply will be a problem. Imports will increase only moderately and U.S. production, with serious capacity limitations, will increase less than 1% annually. This means that, by 1990, 280 million fewer gal of toluene will be available as an octane blendstock than there was in 1980.

Mixed-xylenes demand will grow only 1.5% per year on average during the eighties. Through 1990, xylenes will increase from 1.1 billion gal to 1.3 billion gal. The isomers—ortho, meta, and para—will account for more than 80% of the market, dominating that growth.

Debreczeni expects supply to exceed demand during the eighties, so that some of the xylenes can be reblended into the gasoline pool. □

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Styrene: current overcapacity to tighten

This year, styrene producers will be operating their plants at only 79% of capacity—only a very slight improvement over 1980. Is it possible, then, that in a few short years, styrene plant operating rates will be back up over 90% and that styrene supplies will become tight again?

That, according to C. Terry Cheatham, is exactly what is going to happen. Cheatham, who is petrochemicals marketing manager for Monsanto, says that throughout the 1980's, styrene will experience what large-volume commodities usually experience—periods of tightness and high prices coupled with periods of excess capacity and shrinking margins.

Right now, the styrene picture is colored by overcapacity. Cheatham told a joint meeting of the Chemical Marketing Research Association and the European Chemical Marketing Research Association in New York City that capacity at the end of last year was about 8.8 billion lb. Meanwhile, production was only 6.9 billion lb, 7.8% below 1979 levels. U.S. consumption, at 5.7 billion lb, was only 88% of what it was in the previous year.

Nevertheless, Cheatham is optimistic about styrene's future. He sees U.S. demand for the monomer growing at about 5% per year throughout the eighties, with polystyrene remaining the principal stimulus to that growth. If he is right, consumption will hit 9.3 billion lb by 1990.

Much earlier than that, Cheatham expects that much of last year's excess capacity will be used up rapidly. With the help of an economic upturn, styrene producers could be operating at an average 86 to 88% of capacity by the end of next year. In 1984, they may happily find themselves running at 90% of capacity.

At these operating rates, Cheatham warns, an unexpected shutdown that lasts much longer than three weeks of any plant that produces more than 50 million lb per month can create a shortage.

With Cos-Mar's 900 million lb expansion due on stream in 1985, U.S. styrene capacity will grow to 9.7 billion lb. Obviously, Cos-Mar's expansion will relieve the tight supply situation that Cheatham sees developing in the early to mid-eighties. But he thinks the relief will be short-lived. With U.S. demand growing at 4 to 5% per year, he points out that a new, world-scale plant will be required every two to three years, even if export levels of styrene remain constant.

It is difficult to forecast just what future export levels will be. It is too early to assess the full impact of crude price decontrol and the pending decontrol of natural gas, says Cheatham. Nevertheless, he expects U.S. styrene producers to lose some of their feedstock and energy cost advantages in the future.

Certainly, exports have become important to U.S. styrene producers. They exported 961 million lb of monomer in 1979. In 1980, a record 1.2 billion lb of exports helped relieve the pain of a big drop in U.S. consumption.

The major export markets were Mexico, Japan, and Western Europe. Cheatham says that until Mexico's expansion comes on stream next year, almost all of its monomer demand will be filled by U.S. exports. After a slight intermission, Mexico could become a net importer again by the middle of the decade.

Last year, the U.S. exported 204

Nine companies currently produce styrene

Company and plant location	Capacity (millions of lb per year)
American Hoechst	
Baton Rouge	600
Bayport, Tex.	900
Amoco	
Texas City, Tex.	600
Arco	
Kobuta, Pa.	220
Channelview, Tex.	1000
Cos-Mar	
Carville, La.	1300
Dow Chemical	
Midland, Mich.	300
Freeport, Tex.	1450
El Paso	
Odessa, Tex.	250
Gulf Oil	
Donaldsonville, La.	600
Monsanto	
Texas City, Tex.	1500
USS Chemicals	
Houston	120
TOTAL	**8840**

Source: Monsanto

million lb of monomer to Japan. Two expansions, totaling 510 million lb, will come on stream there next year. These expansions will not eliminate Japan's need to import, but they certainly will reduce it.

Canada also has two styrene plants due on stream around 1985. Much of their output will be targeted for exports, particularly to the Far East, and will compete with U.S. material for that market.

Cost, not a shortage of capacity, prodded Western Europe into importing more than 300 million lb of U.S. styrene last year. But oil and gas decontrol may erase that cost advantage.

On balance, Cheatham expects that the U.S. will become a net importer of about 300 million lb of styrene by 1990. New plants being built throughout the world will reduce export potential. And there is a possibility of several hundred million pounds of Canadian styrene coming into the U.S. once that material becomes available.

Only one thing, says Cheatham, can change his opinion that the U.S. will become a net styrene importer. That is technology. Given a significant breakthrough in technology, he says, the U.S. could regain its competitive advantage.

In the U.S. market, monomer growth will be triggered primarily by polystyrene, its largest single end use. Assuming there isn't another recession, polystyrene demand is expected to be up about 7% this year. By 1982, says Cheatham, demand again will exceed 1979 levels. And, using last year's low demand as a base, he estimates that polystyrene demand will grow an average 5½ to 6% per year through 1985. After that, polystyrene's growth rate will again taper off.

Acrylonitrile - butadiene - styrene copolymer and styrene-acrylonitrile polymer will follow a similar pattern. Styrene demand in these markets likely will grow to 900 million lb in 1985, from last year's weak 635 million lb. In the second half of the decade, however, growth rates are expected to drop to about 4% annually.

Styrene-butadiene rubber will be the weak link in styrene's marketing chain. Because of tire downsizing and the switch to radials, Cheatham sees very little growth in this market.

But for styrene, the future looks bright in unsaturated polyester resins. Cheatham sees demand growing 8% annually through 1985 and 6% per year after that. □

CHECKOFF

NEW PLANTS

■ **Butanol**—Resulting from long-term supply agreement with Rohm & Haas, Union Carbide plans to add additional 200 million lb per year of *n*-butanol capacity at Texas City, Tex., oxo-alcohol facility by 1984. Carbide already is adding initial 200 million lb of butyraldehyde/butanol capacity at Texas City, with first half scheduled to come on stream in early 1982 and rest by 1984.

■ **Catalysts**—W. R. Grace's Davison Chemical division in Baltimore plans to expand cracking catalyst additive manufacturing facilities in multimillion-dollar additions at Curtis Bay, Md.; Lake Charles, La.; and South Gate, Calif. Scheduled operation date for all three projects is March 1982.

■ **Chlorine**—Borden plans to build two chlorine recovery units at cost of more than $20 million at Geismar, La., to process wastes from company's nearby vinyl chloride and polyvinyl chloride units. To be finished in late 1981, project will be handled by Jacobs Engineering Group and H. E. Wiese.

■ **Ethanol**—AgriFuels subsidiary of Oasis Petroleum plans to build 33 million gal-per-year (218 million lb per year) plant in New Iberia, La., at cost of $40 million to make fuel-grade fermentation ethanol from molasses, sorghum syrup, cane syrup, and bagasse. Pedco International will conduct project, scheduled for completion in third-quarter 1982.

■ **Hydrogen**—Amoco Chemicals part of Standard Oil (Ind.) plans hydrogen recovery plant with capacity of 21 million scfd at its olefins complex in Chocolate Bayou, Tex. Product, 95% pure hydrogen, will be shipped to other Amoco plants on Gulf Coast. Completion is scheduled for late 1982, and engineering and construction contract has gone to C. F. Braun subsidiary of Santa Fe International.

■ **Natural gas liquids**—Enserch Corp. of Dallas plans to build plant near Chico, Tex., with capacity to process 30 million cu ft of natural gas per day from various untreated streams to produce combined 3000 bbl per day of ethane, propane, butanes, and natural gasoline. Operation is scheduled to begin in fourth-quarter 1981.

■ **Polybutene**—Exxon Chemical Americas has begun engineering work on 67,000 ton-per-year unit for as yet unspecified location. To be completed in late 1983, plant will bring company's total polybutene capacity to about 100,000 tons per year.

■ **Silicon**—Union Carbide plans to build 1000 metric-ton-per-year polycrystalline silicon plant at unspecified location in Pacific Northwest to begin production in late 1984. Plant will use Carbide's technology for silane feedstock production and technology from Komatsu Electronic Metals Ltd. of Japan for silicon deposition. Product will be high-quality silicon ingots primarily for semiconductor industry.

■ **Vinyl acetate**—Union Carbide has completed first half of 200 million lb-per-year expansion at Texas City, Tex. Present expansion increases total vinyl acetate capacity there from 350 million lb to 450 million lb; second phase slated to push capacity to 550 million lb in 1982.

NEW LABORATORIES

■ **Exxon Chemical** has new $23 million chemical technology center under construction in Baytown, Tex. Space will be 90,000 sq ft in administration/laboratory building and 70,000 sq ft in support areas.

■ **J. M. Huber Corp.** has opened a corporate plastics laboratory at Macon, Ga., to serve company divisions in fillers, clay, calcium carbonate, carbon black, and silicas.

■ **Kalama Chemical** is constructing a new research and development facility at Kalama, Wash., which ultimately will have a staff of about 25.

■ **Pennzoil** plans a $20 million technology center in Houston. Staff at full complement in about three years will be about 100 scientists and engineers.

BEST AVAILABLE COPY

Troubled European chemical industry shows signs of improving

The Western European chemical industry has been in deep trouble. It still is. But now a few optimists are starting to surface. One of them recently traveled from Europe to New York City to explain why he thinks the industry has at least a 50-50 chance of getting itself out of the mess it's in.

At best, Stuart H. Wamsley told a joint meeting of the Chemical Marketing Research Association and the European Chemical Marketing Research Association, he is an optimist by nature. At least, he claims not to share the pessimism that many others have about the future of the European chemical industry.

Sagging demand. Low growth prospects. Overcapacity. Rising costs. Low or nonexistent profits. Increased import competition. All of these are problems that the European chemical industry has to contend with.

Improved technology. Better use of existing raw materials and prospects for substitute feedstock. Improvement in efficiency. Better planning. More efficient use of assets. And restructuring the industry. These are the tools that Wamsley says the industry can use to reverse its decline of the 1970's and to make the 1980's more profitable.

But Wamsley, who is director of chemical research for W. Greenwell & Co. (London), an investment firm, admits that his optimism is strained by the performance of the industry during the past decade. Between 1973 and 1979, the average annual growth rate of chemical production in Western Europe fell to 3.9%, compared to 9.3% between 1960 and 1973. In the earlier period, chemical production grew at a rate four percentage points higher than overall industrial production. In the latter period, it was only 1.8 points higher.

The profit picture is even more depressing. As a result of the 1973–74 oil crisis and last year's disastrous results, profit margins have been cut more than 50% in the past seven years.

Although Wamsley believes that cost pressures will continue to mount and that profits still will be difficult to come by, he thinks that the industry bottomed out in last year's third quarter and that it now is showing signs of improving.

Demand and the cost-price relationship are not so bad as they had been. Wamsley says that things have gotten no worse for the industry during the first half of this year and probably will improve gradually during the second half.

Still, after last year's near-mortal wounds, which Wamsley says were mostly self-inflicted, the industry has a long and hard road back to respectable profitability. Many observers, with good reason, compare Western Europe's chemical industry with its steel industry. Both have poor growth prospects.

The geographical nature of Europe and its still strongly nationalistic governments will continue to keep its chemical industry "the poor relation" among the major blocs, says Wamsley. Potential import competition from Eastern Europe and the Middle East, highly fluctuating currencies, and a fragmented structure aggravated by low cross-border investment will impede Western Europe's chemical industry growth.

Strong and militant unions make it difficult for some companies to close uneconomic plants. Some governments bolster what Wamsley calls "dead or dying ducks" to prevent increased unemployment.

Despite these problems, he thinks that profitability of Western Europe's chemical industry can be better in the eighties than it was in the seventies. Improved plant efficiency, advances in process technology, energy savings, and industrial restructuring will help keep costs down. More important, chemical company management, says Wamsley, seems eager not to repeat past mistakes.

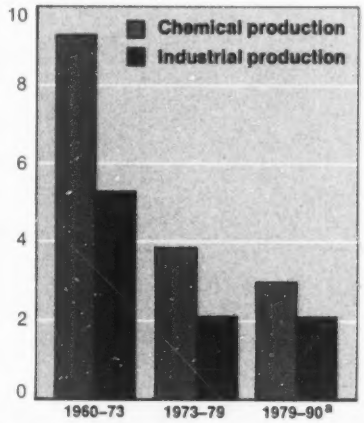
Three factors—costs, selling prices, and demand growth—will dictate the future of the European chemical industry. The outlook for market growth isn't encouraging. Wamsley pegs it at 3% per year during the eighties, which is low by past standards. However, low growth doesn't rule out improved profits.

Europe's petrochemical industry has a severe problem of overcapacity and that problem will persist throughout the decade. It will, that is, unless the industry permanently shutters a large number of plants, Wamsley says. Many plants were shut down, or at least mothballed, last year. But Wamsley says he's afraid that some of them will be reactivated once demand starts picking up.

The trend in costs that the industry will pay for feedstock is unmistak-

West European chemical output growth will slow

Average annual growth rate, %



a Estimated. **Source:** W. Greenwell & Co.

Chemicals profitability takes a beating in Europe

	Profit margin[a]							
	1980	1979	1978	1977	1976	1975	1974	1973
Akzo	2.2%[b]	3.6%	1.9%	0.3%	0.7%	−2.5%	6.2%	7.0%
BASF	5.0[b]	6.6	5.3	5.2	6.7	4.7	6.8	7.4
Bayer	4.0[b]	5.1	5.4	5.1	6.2	4.7	7.2	8.9
BP Chemicals[c]	Loss[b]	5.2	4.2	3.8	9.9	9.0	—	—
DSM	—	0.7	0.3	1.0	2.5	4.0	14.9	7.0
Hoechst	5.0[b]	6.5	5.2	5.1	6.2	5.0	8.7	8.7
Imperial Chemical Industries[d]	2.3	9.0	8.9	10.4	13.1	10.3	15.4	14.4
Montedison	—	—	−4.0	−8.7	−2.0	−2.3	1.2	0.2
Rhône-Poulenc	2.0[b]	4.1	1.7	−0.3	−0.7	−7.7	9.0	5.9
Solvay	4.2[b]	7.2	6.2	6.4	9.4	4.6	9.2	8.6
UCB	—	2.3	0.9	−2.1	2.2	−0.8	6.5	5.3
Dow Europe	9.7	13.1	12.0	12.0	15.8	23.5	25.4	—

a Pretax income as a percentage of sales. b Estimates—figures not yet available. c Pretax and interest. d Excluding profits from oil. **Source:** W. Greenwell & Co.

Ethylene feed and markets—how Europe and U.S. compare

Ethylene feedstock, %	1979 Western Europe	1979 U.S.	1986 Western Europe	1986 U.S.
Ethane	na	53%	3.5%	44%
Propane	na	18	1.4	11
Butane	na	2	9.7	1
TOTAL	2.5%	73%	14.6%	56%
Naphtha	90.0	14	76.5	31
Gas oil	7.5	12	9.0	12
TOTAL	97.5%	26%	85.5%	43%
Refinery gas	a	1%	a	1%

Ethylene end use, %	1979 Western Europe	1979 U.S.	1986 Western Europe	1986 U.S.
Low-density polyethylene	38%	27%	39%	26%
High-density polyethylene	15	17	16	24
Vinyl chloride	18	15	17	13
Ethylbenzene	7	8	5	8
Ethylene oxide	12	17	11	16
Others	10	16	12	13
TOTAL	100%	100%	100%	100%
Thermoplastics	78	67	77	72
Packaging	48	40	48	43

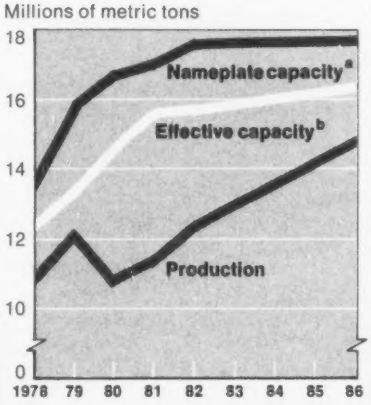
a Negligible. na = not available. **Source:** Phillips Chemical

able. Costs will go up, even though Wamsley thinks that West Europe's chemical producers will become less dependent on the Organization of Petroleum Exporting Countries.

Last year, European naphtha prices dropped from $380 per metric ton in the first quarter to $310 in the fourth quarter. The relief was short-lived, however. In the first quarter of 1981, prices were back up to $360 and Wamsley sees nothing but higher naphtha prices over the long run. Even the U.S. move to lift restrictions on naphtha exports to Europe will have little effect on the price structure.

These naphtha prices will have an important bearing on the cost of Europe's petrochemical feedstock. About 90% of Western Europe's ethylene production is based on naphtha. And, although some production will be switched to light feeds from North Sea gas, naphtha still will account for more than 75% of ethylene output by 1986, according to Stephen A. Franck, planning staff associate at Phillips Chemical.

European ethylene operating rates to improve



a As of end of year. b 32% of operating capacity, which is nameplate capacity corrected for startup and closing dates in a given year. **Source:** Phillips Chemical

Despite rising costs, pricing (usually inadequate to support a profit) has been a major weakness of Europe's chemical industry for a long time. According to Wamsley, that weakness is becoming irreparably damaging.

He insists that pricing is the major weapon the industry has left to recover from "its very nearly successful suicide attempt" last year. True, demand was down in 1980 and chemical imports from the U.S. were up. But Wamsley says that chemical companies exaggerated their impact.

At long last, he says, some responsible chemical companies in Europe seem to be getting prices up as far and as fast as possible. Certainly not all price increases are sticking, but there have been some successes and the signs are encouraging.

According to Wamsley, some of these price hikes have achieved only bare-minimum profitability. There is still a long way to go before they will support reinvestment levels or any other measure of adequate profits.

Too often, managers of European chemical companies have emphasized market share at the expense of profits. Many still do. Wamsley believes that this is the wrong approach because a 1% swing in prices has the same effect on profits as a 5% swing in volume.

In no small way, the recent damaging price cuts in Western Europe's chemical industry have been in response to import competition, particularly from the U.S. But Wamsley believes that European producers reacted to the threat of U.S. imports at low prices, not to the actual volume of imports. Except for a few products, volume was really low.

Wamsley also expresses fear that the industry is tilting toward protectionism, which would be a disaster. Among other things, that would curb research and development, trigger improper pricing policies, and lead to an inefficient industry.

For Western Europe's chemical producers, these developments could be costly, because they export about 40% of their output. By comparison, the U.S. exports only 12% of its production and Japan ships out only 9%.

If European chemical companies want to worry about U.S. exports, Wamsley advises them to worry about U.S. chemicals moving into developing countries. Although starting from a much smaller base, developing countries' demand for chemicals will grow more rapidly than in industrialized nations. European companies, he says, should be competing more strongly for these markets.

Burdened with all of these problems and faced with a lowly 3% average annual growth, the long-term future of Western Europe's chemical industry is in its own hands. New technology can help. Although product innovation may be a thing of the past, technological developments that reduce operating costs or improve processing can boost profitability.

Proper planning will be essential. This will involve not only capital investment and technical improvements, but a much more efficient use of assets. With overcapacity destined to be a long-term problem, chemical companies will face some tough decisions about closing plants. But the decisions will have to be made, says Wamsley.

To Wamsley, the industry has only two choices—accept continuing low profits with its damaging consequences or stop being its own worst enemy. □

Sulfur faces delicate supply-demand balance

The days of plentiful sulfur supplies, so apparent in the second half of the 1970's, are over. But that doesn't mean that sulfur producers can count on huge, continuous shortages to prop up prices.

What's in store for the world sulfur market is a delicate balance between supply and demand that will be sensitive to shocks from either side. Accompanying these shocks will be sharp price fluctuations, caused primarily because "voluntary" sulfur production, such as Frasch sulfur output, will be supplying a declining share of the market.

That's the way that Kenneth Gilbert, research manager for British Sulphur Corp. (London), sees the world sulfur business for the remainder of the eighties. He told a joint meeting of the Chemical Marketing Research Association and the European Chemical Marketing Research Association that Frasch sulfur's share of the western world's market will decline from this year's 30% to 25% by 1990. Recovered sulfur's share, meanwhile, will rise from 59% to 63%.

Other sources of sulfur also will become more important. Imports from communist countries will provide a small, but larger share of the market by 1990. Canadian inventory that has been stockpiled in sulfur vats will be broken down and shipped to market.

Balancing out expected supply and demand, Gilbert says that the two will be closely matched between 1981 and 1984. In these years, out of a market ranging from 30 million to 34 million metric tons, there will be a supply deficit of 147,000 to 285,000 metric tons. That shortage, however, is significantly smaller than the 830,000-metric-ton deficit that was chalked up in 1979.

In the mid-eighties, the supply-demand balance likely will swing into a surplus. Then it will tighten up again before the end of the decade.

The more relaxed market of the mid-eighties and its accompanying lower prices reflect the impact that three important new sources of sulfur will have on the world market. They are new Polish Frasch sulfur, Saudi Arabian output, and recovered sulfur from the U.S. Overthrust Belt.

Canadian sulfur inventories, which had been building up rapidly until 1979, are a special case as far as sulfur supply is concerned. With natural gas output booming in Canada, the volume of recovered sulfur also rose. Transportation to ports for export couldn't keep up with it. As a result, Canadian inventories of recovered sulfur hit almost 21 million tons in 1979. Only last year, when production plateaued and transportation facilities improved did Canada's sulfur export capability overtake production. In the years ahead, as these vatted stocks are broken down and remelted, Canadian sulfur will play an increasingly important role in world sulfur supply.

Gilbert estimates that Canadian production will remain in the 6.2 million to 6.4 million metric ton range for the remainder of the decade. Declining output from existing gas recovery plants will be offset by new plants plus an increase in sulfur recovery from tar sands.

In the U.S., a major increase—perhaps as much as 3 million metric tons by 1990—will come from gas recovery. The big factor will be the Rocky Mountain Overthrust Belt, where Amoco and Chevron already are building plants.

Mexico will become a more important factor in recovered sulfur with output slated to rise from 168,000 metric tons to 950,000 metric tons by 1990. In South America, 60 to 70% of sulfur output comes from Venezuela's oil refineries, but Brazil is expected to build up rapidly from a small base.

In Western Europe, recovered sulfur output probably will increase an average 0.8% per year during the eighties. Starting next year, production from France's Lacq field will start declining. West Germany, the only other significant source, isn't expected to boost its output much beyond 850,000 metric tons by 1990.

Three large sulfur-from-gas plants in Saudi Arabia will fuel a 9.2% average annual growth rate for Asia. Iran's prospects still are uncertain and Japan, whose production comes entirely from crude oil refining, will exhibit a slow, steady growth.

Gilbert thinks the key to Saudi Arabia's sulfur will be its ability to move supplies into the export market. By next year, Saudi production will reach 1 million metric tons, but lack of infrastructure probably will limit exports to half of that amount.

Over the past few years, Frasch sulfur production has been increased in all three producing countries—the U.S., Mexico, and Iraq. Combined production this year will be 9.6 million metric tons, a 22% increase since 1978. But Gilbert thinks that Frasch production will grow very slowly during the eighties, reaching only 10.6 million metric tons by 1990. It might even decline.

Increased Frasch output during the

Future sulfur supply will be in and out of balance

Thousands of metric tons	1978	1979	1980	1981	1982	1983	1984	1985	1990
PRODUCTION	**24,408**	**25,653**	**25,923**	**27,654**	**29,105**	**30,846**	**31,753**	**32,073**	**37,218**
Recovered	16,384	16,719	17,053	18,004	19,205	20,946	21,753	22,073	26,523
Frasch	7,899	8,834	8,670	9,550	9,800	9,800	9,900	9,900	10,600
Native	125	100	100	100	100	100	100	100	95
Plus imports from communist world	2,631	2,155	2,150	2,050	1,950	1,850	3,050	3,600	3,800
Plus vat breaking/remelt	200	500	1,500	1,600	1,900	1,900	1,700	1,700	1,000
Less unmarketable stock additions	503	585	730	960	860	800	760	500	—
NET SUPPLY	**26,736**	**27,723**	**28,843**	**30,344**	**32,095**	**33,796**	**35,743**	**36,873**	**42,018**
Western world consumption	25,971	28,123	28,733	29,996	31,845	33,477	34,481	35,589	41,543
Plus exports to communist world	400	430	460	495	535	575	610	635	735
TOTAL DEMAND	**26,371**	**28,553**	**29,193**	**30,491**	**32,380**	**34,052**	**35,051**	**36,224**	**42,278**
MARKET SURPLUS (DEFICIT)	**365**	**(830)**	**(350)**	**(147)**	**(285)**	**(256)**	**692**	**649**	**(260)**

Source: British Sulphur Corp.

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early eighties will be the result of rising prices and a tight market. Better plant operations also will help. In Iraq, for instance, improvements have raised salable production to about 700,000 metric tons annually. That was before the war with Iran broke out. Although Iraq had been shooting for 1 million metric tons per year, officials there say they don't expect any improvement until at least 1985.

In Mexico, new boilers have been installed at Texistepec. Mining techniques have been improved and a new mine came on stream early this year at Coachapa. In the U.S., there also is a new Frasch mine at Caillou Island, La.

Native refined sulfur has become almost insignificant on the world market. Both Argentina and Colombia have closed mines, and output has been dropping in most other South American countries.

The source to watch, however, is the communist countries, Gilbert says. Ever since Poland became a leading sulfur producer, the communist world has been a net sulfur exporter.

Gilbert cites a disruption in Polish sulfur supplies as one of the major reasons for the recent shortage. In 1979, severe weather hampered deliveries. Then the thaw flooded one of its mines. Later Gdansk, the port used to export sulfur, was hit with labor disputes.

What Poland needs now is a new mine to boost production enough to satisfy both Eastern bloc and western customers. This may not happen until 1984 at the earliest, says Gilbert. Meanwhile, even assuming that the Poles improve production at existing mines, they will be hard-pressed to keep exports to the West from falling for the next two years.

Analyzing all potential sources of sulfur, Gilbert estimates that western world production will increase 4.4% annually until 1985, then taper off to a 3.3% average annual growth rate through 1990. Pumping communist bloc exports into the equation, total sulfur supply for the West will jump from 30 million metric tons this year to 42 million metric tons in 1990. That represents an average annual growth rate of 5.5% during the first half of the decade and 2.7% in the second half.

Demand for sulfur likely will grow slower than supply until 1985. After that, demand growth will outstrip supply growth. That's why Gilbert sees the sulfur supply-demand balance moving from shortage to surplus to shortage again. □

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May 25, 1981

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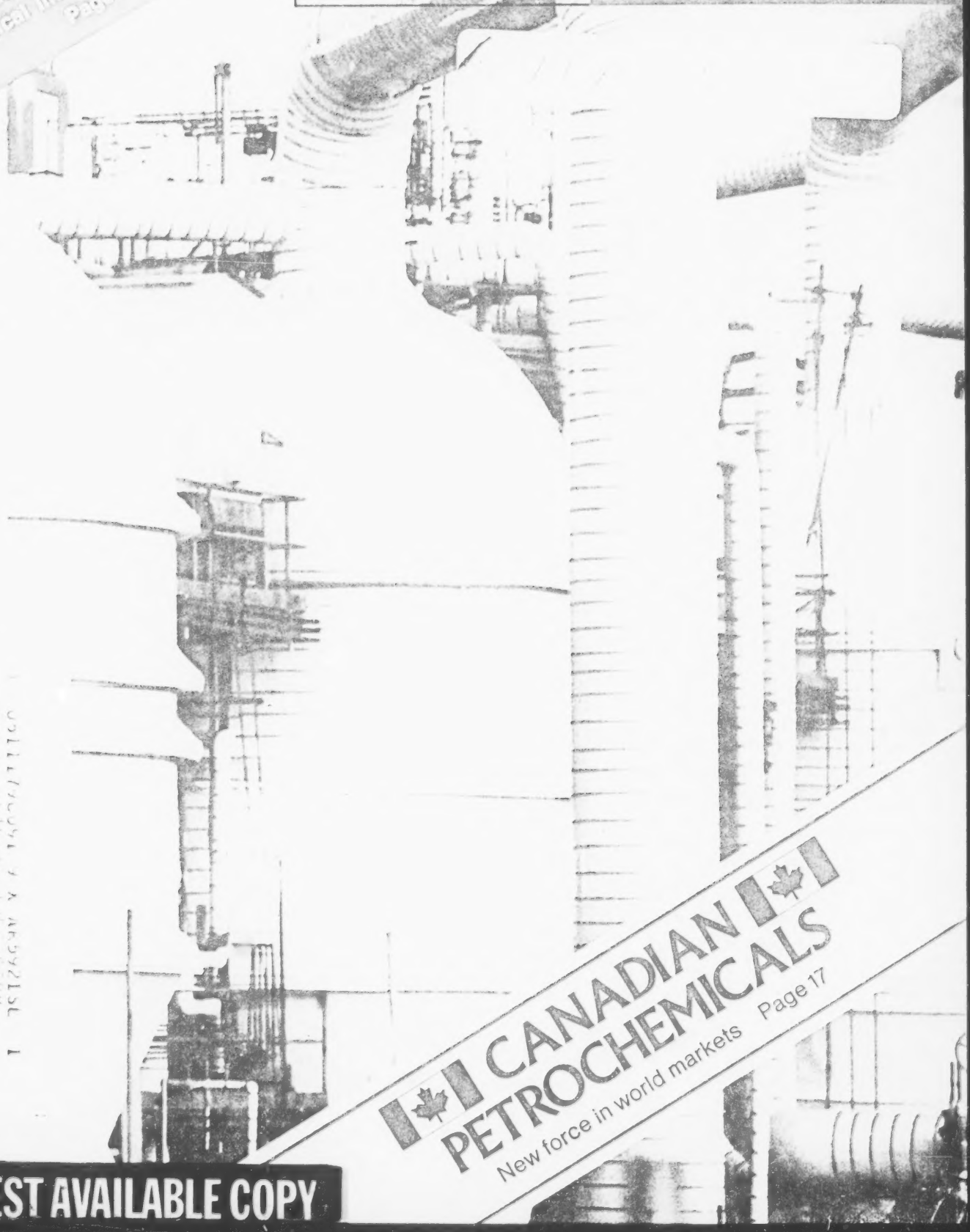

CANADIAN PETROCHEMICALS

New force in world markets Page 17

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May 25, 1981
Volume 59, Number 21
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Chemical & Engineering NEWS

Cover: Dow Canada's new complex in Ft. Saskatchewan, Alta., near Edmonton

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- ***George A. Keyworth,*** *head of Los Alamos' physics division, nominated as science adviser to President Reagan.* ***Page 4***
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department will seek other support for research that will not be bound by agreements with Hoechst, though the company will have first refusal on all research proposals.

Mass General has chosen biochemist Howard M. Goodman, now at the University of California, San Francisco, to head the department, which the hospital has been planning for many years. The department will have 50 staff members, including Goodman and five senior investigators, when or soon after it opens in August. Within three years, the department will move into a new, $15 million building and its staff will increase to 100 persons.

In addition to about $50 million in operating expenses, Hoechst will pay for design, renovation, and equipment of existing space, as well as for construction and equipment of space in the new research building. The new building is slated for completion in September 1983. □

Estimate of natural gas potential drops

The remaining potential for production of natural gas from conventional sources in the U.S. has dropped somewhat in the past two years—from 1019 trillion cu ft at the end of 1978 to 913 trillion cu ft at the end of 1980. But added to proved reserves, the total of 1100 trillion cu ft indicated as remaining to be produced is about twice the cumulative amount produced in the U.S. throughout the entire history of the natural gas industry.

These results sum up the latest biennial evaluation of remaining gas potential by the Potential Gas Committee. The group is an independent committee of more than 100 representatives of the natural gas industry, federal and state agencies, and academic institutions—mostly geologists and petroleum engineers actively engaged in exploration and drilling activities. Publication of the committee's formal report is slated for early June. The report will be available from the committee, headquartered at the Potential Gas Agency, Colorado School of Mines, Golden, Colo. 80401.

The committee divides its estimates into categories depending on the stage of exploration of an area and the amount of available data on which to base the estimate. Thus, "probable" resources are those associated with further development of fields that already have been discovered. "Possible" resources are those estimated to occur in new fields to be discovered in basins or provinces where natural gas production has been established from comparable formations. "Speculative" resources are those estimated to exist in provinces or basins where no gas production has been established or from formations that haven't previously been established as productive.

For the drop in total resource potential from the end of 1978, about a third to a quarter of the decrease can be attributed to transfers from potential resources to proved reserves through drilling and discovery. The remainder of the decrease results from a re-evaluation of resources.

Two trends have appeared over the two-year period since the previous evaluation. One is an indication that more resources exist in the deeper parts of sedimentary basins (more than 15,000 feet) than previously estimated. The committee notes that there has been more drilling to deeper depths in onshore basins, as well as the availability of better-quality geophysical information.

In 1977, 472 wells were drilled below 15,000 feet in the entire U.S., including offshore regions. In 1980, 712 wells were drilled to below 15,000-foot depths.

The second trend is that fewer resources are estimated to lie in offshore regions than previously thought. Reflected in the new estimates, the committee says, are the disappointing results from offshore exploration in the Baltimore Canyon area of the Atlantic continental margin and in the Gulf of Alaska.

Also reflected in the reduction is a greater quantity of data on the Gulf Coast offshore region, which the committee now feels has reached maturity both as to exploration and production. There also have been transfers in this region from potential resources to proved reserves and production. □

Potential gas resources in U.S. are 913 trillion cu ft

Trillion cu ft	Probable	Possible	Speculative
Lower 48 states			
Onshore	151	264	196
Offshore	34	65	58
Alaska			
Onshore	6	16	28
Offshore	2	13	80
TOTAL	**193**	**358**	**362**

High-temperature alloys debut

The first three of a new family of high-temperature alloys for applications such as aircraft engines and industrial gas turbines have been introduced by Inco Ltd., the Canadian metals company.

John Benjamin, general manager for the alloy project, says the new materials will let operators run gas turbines at higher temperatures for increased efficiency or to gain increased lifetime for parts at current operating temperatures. Inco has future plans to market these alloys for high-temperature applications in petrochemical plants and in fossil fuel and nuclear power plants.

The alloys gain enhanced high-temperature strength through dispersion of a refractory oxide such as yttrium oxide in a mechanical alloying process. In this process, the oxide is milled at 0.5 to 1% concentrations in a high-energy ball mill with other metal powders such as nickel, chromium, and a master alloy. The result is a powder feed for extrusion in which oxide and metals are uniformly dispersed.

The powder is heated to 2000° F in an extrusion chamber under an inert atmosphere and extruded into bar or sheet. Bar is hot-rolled and given a heat treatment to develop coarse, elongated grain structure. Sheet is both hot- and cold-rolled, then heat-treated to develop a coarse, pancake-like grain structure.

Advantages of mechanical alloying include uniform oxide dispersion; ability to use reactive metals like aluminum, chromium, and titanium; and production of nonpyrophoric powders for extrusion. The technique was developed jointly by three Inco subsidiaries. Huntington Alloys, Huntington, W.Va., and Wiggin Alloys, Hereford, England, worked on alloying and production of mill forms. Daniel Doncaster & Sons, Sheffield, England, contributed forging and machining of parts. The three firms also are participating in marketing the alloys.

The alloys won't be cheap, ranging in price from $50 to $150 per lb. However, Benjamin says these prices will be competitive with other advanced-technology alloys based on powder metallurgy or directional solidification, but the Inco alloys' stress resistance and resistance to corrosion from carbon dioxide and sulfur dioxide in combustion turbine atmospheres will be superior. □

Chemical capacity use bouncing back

U.S. plant use rates have recovered from last summer's low point but still trail levels of a year ago; polymers lead the way

William F. Fallwell, C&EN Washington; Bruce F. Greek, C&EN Houston

Although the business recovery in U.S. basic chemicals and polymers has shown signs of stalling in the past few months, progress has been considerable since the recession's low point last summer. A telling signal, and one that should cheer optimists on chemicals' chances in the next business expansion, is an upswing in plant use rates, especially in polymers. Such rates are important to the industry's pricing strength and hence to profits and new investment.

C&EN's semiannual capacity use survey finds the rate in basic chemicals climbing to an unweighted 73% of the nameplate total in the first quarter of 1981 from 66% in third-quarter 1980. The new figure is about halfway recovered to the 79% level of first-quarter 1980 before the recession began. The peak rate of the most recent business expansion was 81% in third-quarter 1979.

Polymers have done even better. The leading thermoplastics and synthetic fibers have brought plant use up to an unweighted average of 82% in the first quarter of 1981 from 65% in third-quarter 1980. Polymers are not far behind the 85% level they reached in first-quarter 1980 at their best point in the previous business expansion.

Within polymers, the fiber group stands out. Fibers' plant use in first-quarter 1981 rose to 85%, close to their 86% rate a year ago. Plastics are still somewhat lower at 78% and have not yet approached their 84% rate of first-quarter 1980.

C&EN's survey measures 32 leading basic chemicals, the five top thermoplastics, and the six major fiber types. Included in the survey are data on plant use compared to plants' maximum effective capacity, the practical limit of plant operation over a year ago. Such rates run from 85 to 95% of the nameplate totals because of variable shutdowns for maintenance and product mix changes.

Based on effective top capacity, basic chemicals ran at 80% in the first quarter of 1981. This is up from 72% in third-quarter 1980 but below 86% in first-quarter 1980. Fibers hit 90% of their effective top capacity in first-quarter 1981. Their rate was way up from 70% in third-quarter 1980 but shy of the group's 91% peak in first-quarter 1980.

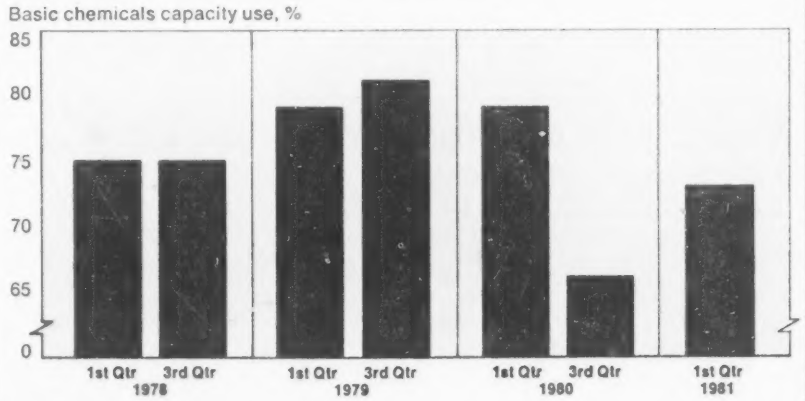
Behind the overall nameplate capacity use figures lie generally diverging trends in capacity and production growth. In basic chemicals, the 32 in the survey had a capacity increase of 4% to 513 billion lb per

Polymer plant use is not much behind a year ago

Billions of lb	First-quarter 1981 Capacity (nameplate)	First-quarter 1981 Capacity use: Nameplate	First-quarter 1981 Capacity use: Effective	First-quarter 1980 Capacity (nameplate)	First-quarter 1980 Capacity use: Nameplate	First-quarter 1980 Capacity use: Effective
Plastics						
Polyethylene, low-density	9.0	92%	98%	8.7	92%	98%
Polyvinyl chloride	7.8	77	89	7.6	86	100
Polyethylene, high-density	6.4	75	79	5.6	86	91
Polypropylene	5.5	76	84	5.2	80	89
Polystyrene	5.4	72	84	5.4	75	88
AVERAGE		**78%**	**87%**		**84%**	**93%**
Synthetic fibers						
Filament yarn						
Polyester	1.9	82	87	2.1	75	80
Nylon	2.0	88	94	2.1	86	92
Olefin	0.90	69	73	0.92	72	76
Staple						
Polyester	2.8	93	99	2.7	97	103
Nylon	1.0	85	90	1.0	86	91
Acrylic	0.83	93	99	0.84	98	104
AVERAGE		**85%**	**90%**		**86%**	**91%**
OVERALL AVERAGE		**82%**	**89%**		**85%**	**92%**

Sources: Industry sources, Textile Economics Bureau, Society of the Plastics Industry, C&EN estimates

Nameplate capacity use is recovering



Sources: Industry, C&EN estimates

Chemical plant use is still down from a year ago

Billions of lb per year unless otherwise noted[a]	First-quarter 1981 Capacity (nameplate)	First-quarter 1981 Capacity use: Nameplate	First-quarter 1981 Capacity use: Effective	First-quarter 1980 Capacity (nameplate)	First-quarter 1980 Capacity use: Nameplate	First-quarter 1980 Capacity use: Effective
Petrochemicals—olefins and aromatics						
Ethylene	40.0	68%	76%	37.0	84%	93%
Propylene (chemical)	23.5	58	64	20.5	79	88
Butadiene[b]	4.6	61	68	4.7	75	83
Benzene (bg)	2.5	68	76	2.6	70	78
***p*-Xylene**	5.6	86	91	5.3	70	74
Petrochemicals—C_1 derivatives						
Ammonia (mt)[c]	24.0	83	88	24.0	81	86
Urea (mt)[c]	8.0	88	98	7.7	86	96
Methanol (bg)	1.4	90	100	1.4	83	92
Formaldehyde (30% solution)	8.9	66	69	8.5	72	76
Chlor-alkalies						
Chlorine (mt)	14.7	73	77	14.4	84	88
Caustic (mt)	15.6	73	77	15.5	79	83
Soda ash (mt)	10.0	82	86	9.7	85	89
Acids						
Sulfuric (mt)	58.3	74	78	57.5	76	80
Phosphoric (P_2O_5, mt)[d]	11.7	94	99	11.0	94	99
Industrial gases						
Oxygen, **Nitrogen** (total, liquid, ttd)	34.8	63	80	32.4	68	86
Carbon dioxide (ttd)	15.6	69	78	14.1	69	79
Mineral-based inorganics						
Sulfur (total, mlt)	15.4	76	—	14.3	83	—
Potash (mt)	2.9	86	—	2.9	86	—
Phosphorus (mt)	0.55	78	82	0.55	83	87
Plastics monomers						
Styrene	8.9	82	96	9.3	87	92
Vinyl chloride	9.7	66	73	8.7	89	99
Propylene oxide	2.7	62	69	3.0	66	73
Fiber monomers						
DMT/PTA[e]	7.3	71	83	7.3	75	88
Ethylene oxide	6.8	65	73	6.6	84	93
Cyclohexane	3.4	62	65	3.2	85	89
Adhesives and coatings monomers						
Phenol	3.6	69	77	3.6	81	90
Vinyl acetate	2.5	78	82	2.5	79	83
Pigments						
Carbon black	3.7	76	84	3.8	68	76
Titanium dioxide (mt)	1.0	77	91	1.0	75	88
Solvents						
Acetone	3.5	58	65	3.3	77	86
Ethanol (mg)	270	65	69	270	71	75
Methylene chloride	0.83	75	83	0.78	85	94
AVERAGE		**73%**	**80%**		**79%**	**86%**

a bg = billions of gal, mt = millions of tons, tt = thousands of tons, ttd = thousands of tons per day, mlt = millions of long tons, mg = millions of gal. b Includes extraction capacity of steam-cracking olefins plants, dehydrogenation and extraction capacity of hydrogenation plants, and other butadiene recovery capacity. c Some capacity probably still shut down, less than 15% for ammonia and less than 5% for urea. d Includes both wet-process and furnace capacity. e Dimethyl terephthalate plus purified terephthalic acid, not including acid converted to DMT. **Sources:** Industry and government sources, C&EN estimates

C&EN's capacity use indicator—the ground rules

Capacity use at chemical plants is difficult to measure and requires certain assumptions to bring some order to the maze of variables affecting this critical indicator of the industry's health.

With the help of industry and government sources, C&EN measures capacity use as a percentage of both nameplate and effective maximums. Nameplate capacity is the official design capacity of plants at nonstop use all year. Effective capacity is the practical maximum capacity after reductions for maintenance shutdowns and changes in product mix. Effective capacity runs from 85 to 95% of nameplate for most chemicals.

Capacity use is given over a calendar quarter, with no seasonal adjustment. The figures include plants actually running. Figures usually exclude new plants just starting up and old plants knocked out for long periods by accidents or mothballing. As much as possible, capacity figures stay current with expansions and debottlenecking.

Capacity figures do not take into account temporary fluctuations for fuel and electric power interruptions, equipment failure, and feedstock scarcity or substitution. The feedstock variables have been especially important in the past few years, further reducing maximum output for a number of important products.

Products in C&EN's capacity use survey are the same as those in the Key Chemicals and Key Polymers series. These are the core products of the industry, the basis for downstream production of thousands of more specialized products.

year in first-quarter 1981 from a year ago. But their output was down 3% over the year to 383 billion lb to give a weighted plant use rate of 75%.

Nameplate capacity for polymers increased 3% to 43.5 billion lb per year in first-quarter 1981 from a year ago. But output fell 2% to 35.4 billion lb to yield a weighted plant use rate of 81%.

Within polymers, fiber capacity fell 2% over the year to 9.43 billion lb per year. Combined with a 2% production drop to 8.16 billion lb, this helped lever capacity use to a weighted 87% of the nameplate total. Fibers' capacity trimming and general lack of new plant plans in the next few years have industry followers hoping that these long-suffering products finally face a bright financial picture.

In thermoplastics, nameplate capacity still rose 5% to 34.1 billion lb in first-quarter 1981 from first-quarter 1980. Output fell 1% to 27.2 billion lb to put weighted capacity use at 80%.

Overall, the picture from first-quarter capacity use is strong in fibers, fair in plastics, and generally poorer in basic chemicals. Within basic chemicals, however, some inorganics are way up, notably soda ash, phosphoric acid, and potash. Most petrochemicals and organic intermediates are trailing, although strength is evident in ammonia, urea, and methanol. □

Canadian petrochemicals set for big growth

Increasing production capacity gives the industry good position in the export market, but it must deal with uncertainties raised by the highly controversial National Energy Plan

Earl V. Anderson
C&EN, New York

Canada's petrochemical industry is like a promising young golfer with a good shot at winning his first important tournament. He has driven the 18th hole in fine style. His ball rests in the middle of the fairway with an excellent lie. A short chip shot to the green will win him all of the marbles.

There is only one problem. A tricky, swirling wind is blowing and the golfer doesn't know just how hard or from which direction that wind will flare up when he hits the ball.

For Canada's petrochemical industry, its "tee shot" has been an impressive surge of new plant construction that has increased substantially its petrochemical-producing capacity. A good measure of this growth is ethylene capacity: It has grown from less than 1.2 billion lb per year in 1974 to almost 3.5 billion lb last year. Along with this increase in ethylene capacity have come plants to upgrade ethylene into polyethylene, vinyl chloride, styrene, polyvinyl chloride, polystyrene, ethylene oxide, and ethylene glycol. Methanol and ammonia also are very much a part of Canada's petrochemical expansion picture.

Gross fixed assets of the industry have soared from a miserly $860 million in 1970 to almost $3 billion by the end of 1979. Most of this expansion came on stream during the second half of the decade. And most of it went up in Alberta, where a more-than-ample supply of inexpensive natural gas was crying for the petrochemical industry to take advantage of it.

This "tee shot" has given the industry its excellent fairway position. The "chip shot" awaiting it will require the industry to continue building large, economical, world-scale plants to take full advantage of the industry's envious light feedstock position.

That's exactly what the industry is doing. Between 1980 and 1982, it will pump an additional $1.5 billion (Canadian) into new petrochemical units. There's very little doubt that still more capital investment will follow.

In Alberta, for instance, a second ethylene plant is scheduled to come on stream in 1984. A third one is planned and already there is talk of a fourth. Additional downstream units also are being built or planned. Yet another petrochemical complex may take shape in British Columbia.

If all of this additional investment—the industry's "chip shot," comes off as expected, then both Canada and its petrochemical industry can end up as winners.

In addition to the obvious—creating more jobs, contributing to the country's gross national product, and increasing its tax base—Canada will be going a long way toward reversing its historical role as an exporter of natural resources and an importer of finished products.

Canada's blossoming petrochemical industry can make the country self-sufficient in petrochemicals. Its traditional need to import these products will be erased. And the industry's export potential will sweeten Canada's balance of trade in chemicals.

Already there are signs that this is happening. After years of red ink, Canada's chemical balance of trade jumped into the black in 1979. Last year, its chemical trade surplus hit $636 million on the strength of $4 billion worth of chemical exports. That's 20% higher than the previous year and petrochemicals had a lot to do with it.

But if that chip shot facing Canada's petrochemical industry calls for any finesse at all, that finesse lies in its ability to export. Exports are the key to the industry's future.

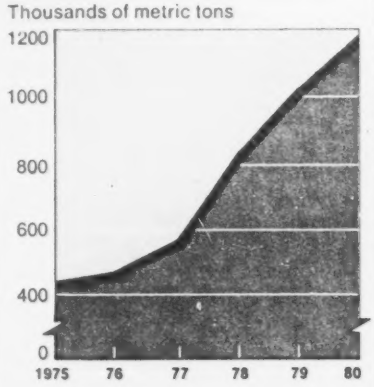
It's nice to have a seemingly endless supply of natural gas as raw material. The industry has that. It's also nice that its natural gas is much less expensive than in many other parts of the world. That helps compensate for the higher construction costs that Canada's climate requires and the higher transportation costs facing the industry.

It also may make sense to build large, world-scale plants. That helps the industry's economics even more. But it doesn't take many of these

Canada's chemical trade moves into the black

Source: Statistics Canada

Canada's ethylene output soars



Source: Statistics Canada

huge plants to satisfy the petrochemical demands of a country whose population is only 23.9 million.

Excess production has to be exported. Fortunately, the Canadian petrochemical industry has the tools to make it a formidable competitor in international petrochemical trade. Its most logical markets are the neighboring U.S. and the Pacific Basin countries.

Canadian petrochemicals already are starting to make waves in some of these markets. So a thriving export business is another "marble" that the petrochemical industry can pick up—must pick up—in the tournament.

But oh that wind! The industry has to finesse its all-important chip shot with Canada's highly controversial National Energy Plan (NEP) swirling around it.

When NEP was unveiled last October, it hit all of Canada like a tropical hurricane. The economic and political repercussions of NEP were immense and quick in coming. The issues surrounding NEP are still not resolved. And how they eventually are resolved will have an important bearing on the future of Canada's petrochemical industry.

NEP's three major objectives are laudable enough:

- "Establish the basis for Canadians to seize control of their own energy future through security of supply and ultimate independence from the world oil market.
- "Offer to Canadians, all Canadians, the real opportunity to participate in the energy industry in general and the petroleum industry in particular, and to share the benefits of industry expansion.
- "Establish a petroleum-pricing and revenue-sharing regime that recognizes the requirement of fairness to all Canadians no matter where they live."

Most Canadians, including members of the petrochemical industry, agree with these objectives. Of the three, most Canadians (or at least most of the business community) consider security of supply to be the most important objective.

Canada has more natural gas than it can use. But it imports about 25% of its crude oil requirements at world prices.

What is causing the furor in Canada is the way in which NEP proposes to achieve these objectives. Not only does NEP have many segments of the oil and gas industry, the petrochemical industry, and other industries in an uproar, it has ignited a long-smoldering feud between the major oil-producing province of Alberta and the Canadian federal government that makes the Quebec separation issue seem like child's play.

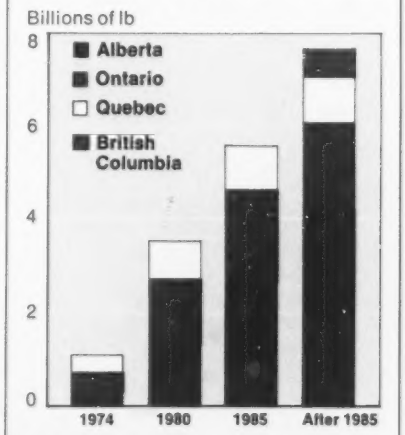
Basically, NEP gives the federal government control over all oil and natural gas pricing and levies a variety of taxes that enrich the federal treasury at the expense of private industry and the producing provinces. The plan also offers the oil and gas industry "for Canadians only" incentives that have non-Canadians paralyzed with uncertainty, if not fear.

NEP's announced goal is to achieve energy self-sufficiency, including oil, by 1990. But critics, although endorsing the goal, say that NEP as written can never achieve it.

Among its many provisions is a petroleum compensation charge, or refinery tax, on all refineries, whether they use imported or Canadian oil. These funds will be used to finance the imported-oil subsidy; that is, the difference between the cost of imported oil and the much lower-priced Canadian oil. The funds likely will cover the subsidy fully by the end of next year, with the help of a "blended" crude oil price that averages the prices of conventional Canadian crude, imported crude, and nonconventional oil.

A new federal natural gas tax applies to both Canadian and export sales. And NEP establishes a new federal petroleum and gas revenue tax (8% initially) applied to net producer revenues from Canadian oil and gas production. This tax is not deductible from federal income taxes, nor will deductions be allowed from "net revenues" for exploration and development expenses.

Alberta will dominate Canada's ethylene capacity



Source: Industry sources

These taxes will change drastically the way the oil and gas pie is sliced. The federal government will be the big winner, mostly at the expense of the producers.

According to federal calculations, its share of oil and gas revenues will jump from 10% to 24%. The amount retained by the producing provinces will slip from 45% to 43%. But companies that do the producing will keep only 33% of revenues, compared to 45% before NEP.

Under NEP, Ottawa will control all Canadian oil and natural gas pricing. NEP establishes a schedule for oil price increases and stipulates that the reference (Toronto gate) price of natural gas will go up 15 cents per thousand cu ft for each dollar increase in the wellhead price of crude.

Despite the proposed price increases, NEP is designed to make certain that Canadians pay less than world price for their oil. Canada's Prime Minister Pierre Trudeau believes that world oil prices are arbitrary and artificial. He is determined not to link Canadian oil price to world prices. Instead, he wants "made in Canada" prices, determined according to Canadian circumstances and need. Finally, Trudeau wants to make sure that the have-not provinces share in the benefits of Canadian oil and gas.

As a result, Canada's blended oil price never will be allowed to exceed 85% of world price or the price of oil in the U.S. (the Chicago price), whichever is less. Natural gas prices will be kept even lower than oil prices, on an equivalent-Btu basis, to encourage consumers to switch from oil to natural gas.

Last year, Canadian natural gas was priced at about 80% of crude oil levels. This year, that figure is expected to drop to 70% and hit 67% by 1983.

Almost everyone familiar with Canada's energy situation agrees that oil prices must go up if the country is to become self-sufficient. Even most companies in the petrochemical industry say that they can live with crude priced at 80 to 90% of world oil.

What most of them conclude, though, is that NEP doesn't raise prices far enough fast enough. As a stimulus to increased oil exploration, they would like to see Canadian crude prices reach those high percentages by 1983 or 1984. Certainly not later than 1985.

NEP won't accomplish that. Ca-

UPI photos

Alberta's Lougheed (left) was infuriated by the energy proposals of Trudeau (right) and Lalonde

nadian crude now is priced at roughly half world levels. By 1984, NEP won't boost it much above 55 to 57%.

Even more distasteful, at least to the oil and gas industry, are NEP's proposals that would "Canadianize" the industry. Of the 25 leading oil companies in Canada, 17 are more than 50%-owned by foreign companies. The 17 account for more than 70% of Canada's oil and gas sales.

NEP will drastically alter the industry's structure. The goal is at least 50% Canadian ownership of oil and gas production by 1990. To do this, NEP will phase out depletion allowances by 1984, except for heavy oil upgrading and enhanced recovery.

In their place, the federal government will offer direct incentives. But these incentives will be paid only to companies that have 50% or more Canadian ownership or control. Companies with less than 50% Canadian ownership are expected to increase that share and will have to provide specific plans for doing so.

In addition, the Trudeau government plans to nationalize, at least partially, the oil and gas industry. It hopes to acquire "several" large foreign-controlled companies, more than likely through Petro-Canada, the state-owned company. NEP also forces oil companies to give Petro-Canada a 25% "carried interest" in all frontier projects.

Petro-Canada's recent $1.4 billion takeover of Petrofina Canada Ltd. is only the start. The government is eyeing other acquisition possibilities, with Gulf Canada frequently mentioned as a potential candidate.

Repercussions from all these proposals were felt as soon as NEP was unveiled. Plans to pump foreign capital and exploration expenditures into Canada were cut back or shelved. Exploration rigs and crews were pulled out of Canada and set up in the U.S., where decontrol offered more promising prospects.

The Canadian dollar fell sharply right after NEP was announced. And the economic impact trickled down through all levels of Canadian business.

On the political front, Alberta rebelled. Alberta's Premier Peter Lougheed and the rest of the province were infuriated at the big switch in revenue sharing that favored the federal government. And they weren't exactly pleased with NEP's schedule of price increases. Alberta officials wanted Canadian crude prices to move up to 75% of world prices by 1984.

Alberta, which accounts for about 85% of Canada's oil production, retaliated in March. It cut its average 908,000 bbl-per-day output about 100,000 bbl. Ottawa responded with a special levy on oil to pay for the additional imports needed to offset Alberta's cutback, then blamed Alberta for the action.

Alberta has threatened to cut production 60,000 bbl per day on June 1 and again on Sept. 1 if the rift between the province and the federal government isn't resolved. And it has held up approval for Alberta tar sands plants, which are sorely needed to replace dwindling reserves of conventional oil.

At press time, the Ottawa-Alberta imbroglio had yet to be resolved. Last month, federal energy minister Marc Lalonde and his Albertan counterpart Mervin Leitch met in neutral Winnipeg—their first meeting since NEP hit Canada. Although they still are a long way from agreement, both say that they made significant progress at Winnipeg and plan to meet again later this month.

Two important issues still separate them—the wellhead price for oil and the revenue split between Alberta and Ottawa. Industry observers, however, are optimistic that something useful will come out of the next meeting.

One possibility is a trade-off. If Ottawa accepts the need for a quick and substantial increase in oil prices, Alberta may not insist on linking Canadian prices to the international market.

A settlement, almost any settlement, is better than being caught in the middle of a provincial-federal struggle. The uncertainty alone is enough to fray the nerves of most Canadian industrialists, including those in the petrochemical industry.

In the final analysis, a sound energy plan is critical to the future of Canada's petrochemical industry. According to James H. Hay, president and chief executive officer of Dow Chemical of Canada, NEP will determine what will happen to the chemical industry and to every other energy-consuming business in Canada. "It overlays all other considerations," says Hay.

Indeed, NEP is the wind that will determine how well the industry plays its chip shot. It certainly will affect feedstock price and availability.

Petrochemical activity centers in four provinces

For the largest part of the industry, that which is weaning on the inexpensive natural gas in western provinces, feedstock price and supply are no problem. NEP reconfirms this preferential feedstock position.

But it isn't so encouraging for the other part of the industry that must rely on crude oil and its derivatives, such as naphtha and gas oil. Encouraging a natural gas, ethane-based industry, as NEP does, may be fine for ethylene and its derivatives. But what about aromatics?

Canada's aromatics industry certainly has no argument with NEP's intent to keep crude prices at 85% of world prices, or lower. What it objects to is one specific statement in NEP. That statement reads:

"The petrochemical industry ... should not plan on using more oil in 1990 than it does now. Canada needs that oil for other purposes. For most petrochemical processors, feedstocks other than oil will do. Gas will be cheaper than oil in Canada."

NEP goes on to say that, if additional oil reserves are discovered in Canada, the government will consider allocating additional oil for petrochemicals. Until then, it thinks that the industry should rely on natural gas, liquefied petroleum gas (LPG), and coal for its feedstock.

Such a position doesn't rest well with the heavy end of Canada's petrochemical industry. Petrosar recently submitted comments to the National Energy Board concerning NEP's impact on the petrochemical industry. Those comments underscore the adverse effect that NEP may have on the industry by curtailing crude oil because "no economic alternative ... and in some cases, no alternative at all" exists to make some petrochemicals, such as aromatics.

As a result, Petrosar thinks that NEP is placing a large part of the petrochemical industry in jeopardy. What better use, it asks, can be made of Canada's crude oil? Petrochemicals offer a better opportunity to upgrade crude to higher value-added products than any other use. The only other alternative to making some petrochemicals, says Petrosar, is to continue importing them. And that hurts the balance of trade. Ironically, Canadian Development Corp. (CDC) owns 60% of Petrosar—20% directly, and another 40% through Polysar, which is wholly owned by CDC.

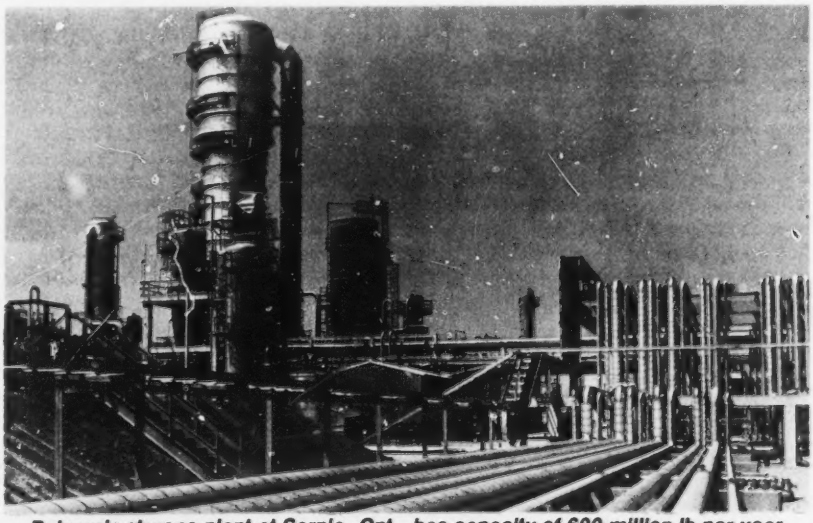
Petrosar presented the National Energy Board with two scenarios that show just how short of some petrochemicals Canada could be in the 1980's if it insists on holding crude supplies for petrochemical plants to present levels.

One case assumes that ethane is substituted for oil-based feedstock to supply all of the estimated growth in ethylene output between 1980 and 1990. In the other case, LPG is the substitute.

Under the ethane-only scenario, Canada would lose 1.2 million metric tons of propylene, 290,000 metric tons of butadiene, 520,000 metric tons of isobutylene, and a whopping 5.5 million metric tons of benzene. With LPG as the substitute, there would be no shortage of propylene. But the shortfall in butadiene and isobutylene would remain almost as high. And the benzene shortage would be just as high.

Translating these shortages into economic terms that politicians can understand, Petrosar points out that Canada would lose $35 billion in gross domestic product and about 600,000 jobs over the 10-year period. Replacement imports, the company warns, would be heavily weighted toward the most upgraded products, such as plastics and fabricated products. Not only would this have the worst possible impact on Canadian employment, it would maximize the negative impact on the balance of trade.

With Canada short on crude oil, its effort to conserve its own supplies and to reduce imports is understandable. But the amount of crude that the petrochemical industry needs is small, compared to total consumption. Petrosar estimates that, on av-



Polysar's styrene plant at Sarnia, Ont., has capacity of 600 million lb per year

erage, the industry will need only an additional 45,000 bbl per day in the 1980's. That's less than 5% of total crude and equivalent demand.

Thus, Canada's petrochemical companies that rely on crude oil are facing a dilemma. For them, there is no economic alternative. No feedstock other than those derived from crude will fill the bill for about 35% of the primary petrochemicals produced in Canada.

Natural gas and ethane are fine for ethylene. LPG is also fine for ethylene as well as propylene and small amounts of C-4's. In time, coal may become an alternate source of petrochemical feedstock. But coal is not yet economical in Canada and may not be until the end of the century.

Aromatics producers, and even olefins producers that use naphtha crackers, may be locked into crude oil. But they are quick to point out that alternatives do exist for oil used as fuel. Among the possibilities are propane for motor fuel, natural gas for heating, hydroelectricity, and nuclear power.

In western Canada, particularly in Alberta but possibly later in British Columbia, natural gas and ethane are the name of the game. The aromatics centers are in the East, around Montreal in Quebec and Sarnia in Ontario.

As a result of NEP's embargo on increased crude oil for petrochemicals, proposed expansions by Petrosar in Sarnia and Petromont in Montreal could not be made. NEP also would affect two aromatics projects in Alberta. There Alberta Energy Co. is teaming up with Esso Chemical Canada to build one benzene unit, and Shell is planning another.

Little wonder, then, that Petrosar says that NEP "improperly ignores economic factors in determining optimum use of crude oil." The company is trying to persuade the government to adopt policies that would foster growth in all three of Canada's existing petrochemical centers—Quebec, Ontario, and Alberta. To do this, of course, Ottawa would have to allot the industry enough crude oil to expand as the market requires.

Like most Canadian companies heavily involved in aromatics and/or butadiene and butylenes, Polysar endorses Petrosar's call for an adequate supply of crude oil. In fact, Polysar, which owns 40% of Petrosar, gets just under half of its raw materials from Petrosar.

Polysar says that natural gas prices in Canada should be allowed to seek Btu parity with crude oil. It also suggests that one way to achieve energy self-sufficiency is to optimize a north-south movement of energy products under a government-to-government agreement between the U.S. and Canada. The company considers this a better alternative than what it calls the "capital intensive" east-west extension of distribution systems within Canada itself.

Because the federal government's announced policy is to keep natural gas prices below those of crude, Polysar's call for price parity between the two no doubt will go unheeded. But there is one thing upon which both factions of the petrochemical industry agree.

That is Canada's need to achieve self-sufficiency in oil as quickly as possible. And many chemical companies have indicated that they don't think the proposals outlined in NEP will accomplish this. Instead, they say, the opposite will happen: It will discourage the search for new oil and gas.

NEP also has other more subtle, but important implications for Canada's petrochemical industry. For instance, some companies with exploration and development interest in oil and gas may be hit hard.

Allied Corp., the U.S. company that recently changed its name from Allied Chemical, is seeking buyers for two wholly owned Canadian exploration and production affiliates. Under NEP's Canadianization incentives, Allied says that the companies (Uno-Tex Petroleum and Union Texas of Canada) would be more valuable to a Canadian-controlled company.

Britain's Imperial Chemical Industries (ICI) and its Canadian affiliate C-I-L Inc. are serious about investing in western Canada's oil and gas. C-I-L and ICI have teamed up in a joint venture with Bralorne Resources and its parent company. But there is some question, given the British background of ICI and C-I-L, as to whether the venture will qualify for the incentives spelled out in NEP. Until that question is answered satisfactorily, spending will be made only "if conditions warrant," according to the companies.

Dow and Monsanto are other for-

New petrochemical units are springing up in Alberta

Company	Product	Location	Startup date	Cost ($ millions, Canadian)	Capacity (thousands of metric tons)
Alberta Energy Co., Esso Chemical Canada	Benzene	Bruderheim	1983	$270	370[a]
	Styrene	Bruderheim	1984	300	400[a]
Alberta Gas Chemicals	Methanol	Medicine Hat	1981	140	764[b]
Alberta Gas Ethylene	Ethylene	Joffre	1984	370	680
	Ethylene	Joffre	1986	470	680
Celanese Canada	Methanol	Edmonton	1982	275	700
C-I-L	Low-density polyethylene	Edmonton	1982	55	68[b]
C-I-L, Trimac	High-density polyethylene	Edmonton	1984	128	100
Dow Canada	Low-density polyethylene	Ft. Saskatchewan	1983	75	203
Dow Chemical of Canada	Ethylene dichloride	Ft. Saskatchewan	1984	135	460[b]
	Vinyl chloride				365[b]
	Chlorine				—
	Caustic soda				—
Du Pont, Alberta Energy Co.	Polyethylene	Edmonton	1984	200	225[c]
Esso Chemical Canada	Ammonia	Redwater	1983	350	616
	Urea				578
Shell, Husky	Benzene	Scotford	1984	na	236
Shell, Nova	Styrene	Scotford	1984	160	300
	Low-density polyethylene	Joffre	1984	215	270
Sherritt-Gordon Mines	Ammonia	Ft. Saskatchewan	1983	300	443
	Urea				385
Union Carbide	Ethylene glycol	Prentiss	1984	330	230

a Petalta project. b After expansion. c Depending on ethylene supply. na = not available. Source: Province of Alberta

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eign-controlled chemical companies with a stake in Canadian oil and gas. Dow Chemical of Canada is associated with Dome Petroleum in oil and gas operations and probably is the chemical industry's leading investor in the field.

In a preliminary assessment of NEP's impact, Dow says that its oil and gas operations, through its wholly owned subsidiary, Maligne Resources, will be "substantially affected" by NEP. The company is developing strategies to comply with NEP's complex regulations. However, Dow says that its expected cash flow over the next five years will be reduced significantly as a result of NEP. Consequently, its ability to help finance development of Canada's resources will be reduced as well.

Dow and other foreign-controlled chemical companies in Canada are worried about one other aspect of NEP, too. They are afraid that the federal government's Canadianization of the oil and gas industry may extend eventually to other industries as well, including the internationally oriented petrochemical industry. That industry, in fact, already has been told that its operation may be monitored.

Dow Canada spelled out the implications of such a development in a background paper on NEP. Dow Canada is a wholly owned subsidiary of U.S.-based Dow Chemical. But if Canadian ownership were imposed on Dow Canada, it no longer would have free access to its parent's latest research and technology, to its investment capital, or to its well-developed international marketing organization. Other multinational companies operating in Canada would be hit the same way.

Other sources of capital could be developed, but the cost would be higher and the amounts probably smaller. Technology would be more costly and slower in coming. There probably would not be enough of the right kind.

Most important, perhaps, is the potential loss of an international marketing setup. Canada's petrochemical industry is being designed for exports. It's what justifies building world-scale plants there in the first place—plants that will produce more than Canada possibly can consume.

True, Canadianized chemical companies could build up their own international marketing groups. But they wouldn't be so effective as the original and they wouldn't be so economical.

It also would take time to develop these groups, and time is what Canada's petrochemical industry doesn't have. New petrochemical industries are sprouting up in other parts of the world—Mexico, Saudi Arabia, and other Middle Eastern countries, for instance. All of them are eyeing the same export markets.

Right now, Canada's petrochemical leaders believe they have the jump on this potential export competition. But they can't afford any delay. Being stripped of an existing international sales force would cost them dearly.

Fortunately for the industry, NEP isn't set in concrete. Many regulations haven't been implemented yet. And a settlement of the Ottawa-Alberta dispute may lead to changes in the plan's basic tenets.

Nor does NEP represent a definitive petrochemical policy for Canada. Some hint of what Canada's eventual petrochemical policy might be could surface soon, perhaps within the next month.

The government is preparing a position paper on its petrochemical industry, with emphasis on energy and feedstocks. Since energy is what NEP is all about, this position paper could go a long way toward clearing up uncertainties it has generated.

Until those uncertainties are cleared up, the petrochemical industry will continue to line up its chip shot with the unpredictable wind of NEP swirling around it. □

British Columbia—new to petrochemical game

Although it doesn't have anywhere near so much natural gas as Alberta, British Columbia hopes to become the fourth petrochemical-producing province in Canada.

If it wins government approval, the biggest petrochemical project in British Columbia could be that of a consortium made up of Canadian Occidental Petroleum, Dome Petroleum, Westcoast Transmission, and the Japanese Mitsubishi companies. Cornerstone of the $2.1 billion project, which will be built in the Kitimat area, is a 600 million lb-per-year ethylene unit. The consortium also will produce ethylene dichloride, vinyl chloride, polyvinyl chloride, and polyethylene.

The companies now are making feasibility studies. Construction could start in 1983, with startup in late 1985.

In addition, both Ocelot Industries and Westcoast Transmission plan to build large methanol plants at Kitimat.

NASA holding its own against budget cuts

All major programs would continue, but at slower pace than in budget proposed by Carter; space shuttle would get biggest piece of the pie

The accomplishments of most research and development programs are barely seen by most people, if they are visible at all. But the results of R&D efforts of the National Aeronautics & Space Administration are often spectacularly visible and breathtaking. To get these results, however, NASA spends an awesome amount of money.

NASA is the largest funder of R&D in the federal government excepting the Department of Defense. The agency's proposed $6.1 billion budget for 1982 includes more than $4.9 billion just for R&D, the remainder going for program management and construction. Although this figure is $549,000 less than that proposed in January by the Carter Administration, it is still a 13% increase above the fiscal 1981 level.

Acting NASA Administrator Alan M. Lovelace says the proposed funding "does not contain all that we believe NASA could effectively pursue to exploit our potential [but] it does provide adequate amounts for development of the . . . space transportation system and [provide] balanced programs."

The 10% cut from the original 1982 budget would provide for continuation of all major NASA programs, but some would have to be slowed down, and any new projects would be halted. The space shuttle program, far and away NASA's largest, would get about $2.2 billion, just $36 million less than sought in January. This would allow for the continued construction of three more shuttle orbiters, two sets of solid rocket boosters, and maintain the option for a fifth orbiter.

The funding situation for other large projects varies. Support for the space telescope would remain about the same as in 1981 at about $119 million. This telescope, launched from the shuttle—perhaps in 1985—will provide a resolution 10 times greater than Earth-based telescopes, and will have the ability to see objects only 2% as bright.

The vaunted spacelab is being cut. The proposed support of $110 million is 21% less than originally suggested, and this would leave it 27% under its funding for 1981. NASA says the money would go toward buying a second spacelab from the European Space Agency, for making a spacelab-to-orbiter tunnel, and testing and simulation of equipment.

The proposed budget also includes $108 million for the Galileo mission to study the atmosphere of Jupiter, up almost $45 million from 1981, but not enough to keep the mission on schedule; the gamma-ray observatory development, almost eliminated at $8 million, down from an original request of $52 million; and the Venus orbiting imaging radar for mapping the hidden surface of Venus, cut 75% to $10 million from the original budget figure.

Another program that was cut but still is getting a large increase over 1981 is for materials processing in space. The $27.7 million proposed for 1982 would be a 48% rise over last year, but considerably less than the $32.1 million proposed in January. The program will use the space shuttle to obtain experience with a number of processes, often with an eye on possible commercialization. Some of these include acoustic and electrostatic control of materials in containerless processing, growth of bulk semiconductor single crystals in a low-gravity environment, and separation of biological materials by electrophoresis.

There is a long list of projects that have been halted or eliminated. Some of these are the pullout of a U.S. spacecraft in the international solar polar mission, which was to study the sun from a point far above the plane of the solar system; cancellation of the start of a national oceanic satellite system; elimination of direct funding by NASA of energy technology activities; and elimination of all new initiatives in the space sciences division and aeronautics and applications division.

The breadth of the cuts to NASA's budget, if not the depth, has some people worried. This concern was expressed by Bruce C. Murray, director of the Jet Propulsion Laboratory, at recent NASA budget hearings before the Senate Subcommittee on Space Science & Applications. Murray says the NASA cuts mean that "this decade will surely witness America's abdication as the world leader in space exploration." He believes that postponement of projects for exploration, such as the Galileo and gamma-ray projects, is evidence

Most NASA programs would get increases

$ Millions	1980	1981[a]	1982[a]	% change 1981–82
Space transportation	$2385	$2734	$3136	14.7%
Space shuttle	1871	2003	2194	9.5
Space flight operations	447	676	911	34.7
Expendable launch vehicles	67	54	31	−42.6
Space science	601	538	584	8.5
Physics and astronomy	337	321	325	1.5
Planetary exploration	220	176	215	22.6
Life sciences	44	42	44	3.2
Space and terrestrial applications	344	338	378	11.6
Space applications	332	332	373	12.5
Technology utilization	12	7	5	−28.6
Aeronautics and space technology	427	385	390	1.4
Aeronautical research	308	272	265	−2.7
Space research	116	111	125	13.2
Energy technology	3	2	0	−100
TOTAL	**$3757**	**$3995**	**$4488**	**12.3%**

a Proposed by Reagan Administration. **Note:** Columns may not total exactly because of rounding. **Source:** NASA

of a "conscious effort to dismantle the deep space capability of this country."

The singular success of the flight of the space shuttle orbiter *Columbia* last month could go far in ensuring that public support continues for NASA explorations (C&EN, April 27, page 17). Cuts to the budget for space operations may, however, slow the rate of research activities that will be done via the shuttle.

NASA has scheduled 37 space shuttle flights by the end of 1985. Payloads for these flights already have been determined. NASA says that more than 40 government agencies, commercial firms, or foreign countries have ordered space aboard the shuttle, for which NASA is charging about $500 million. This is said to be about half what it would cost to put up satellites by more conventional means. These payloads include at least 37 communication satellites, half of which will be launched for foreign countries.

There are also a number of smaller projects, called "getaway specials," that will go up with the shuttle. These will be items that can fit into a special cylinder, and weigh less than 200 lb. Cost of a getaway special is less than $10,000, and nearly 300 have been purchased so far. Many of the sales are to drug and chemical companies for testing the effects of weightlessness on the formulation or production of products. Other research projects will be prepared by universities.

A lot has been made of the military applications of the space shuttle capability, applications that NASA does not deny. Eleven of the planned shuttle flights are reserved specifically for Defense Department use and will carry no civilian payloads. These would appear to be for observation and secure communications satellites, items which now are being launched by expendable rockets but would be cheaper and more reliable if launched with the shuttle.

When technical problems occurred during the shuttle's development, funding for the project apparently was almost halted, but DOD stepped in to help fund the program. According to a recent report by the General Accounting Office, DOD spending for the space transportation systems increased from $1.2 billion in 1978 to more than $2.8 billion for 1982. This would allow assistance not only for the orbiter, but also the upper-stage payload launching system, spacelab development, launch and landing facilities, and personnel training.

David Hanson, Washington

Federal Alert—*new legislation*

This C&EN report highlights legislation introduced between March 18 and May 14. Senate and House bills are listed under subject area by number, primary sponsor, and committee(s) to which referred.

SENATE

Agriculture. S. 884—Helms (R.-N.C.). Redefines, extends USDA's agricultural research programs; referred to Agriculture, Nutrition & Forestry.

Antitrust. S. 795—Thurmond (R.-S.C.). Provides that export joint ventures can be challenged under the antitrust laws only if they have substantial effect on commerce within the U.S.; referred to Judiciary.

Environment. S. 1107—Simpson (R.-Wyo.). Requires that court challenges of federal actions that are of a purely local or regional nature be filed in the states or regions in which the subject of the suit is found; referred to Judiciary.

Insurance. S. 1096—Kasten (R.-Wis.). Allows product sellers to form product liability risk retention groups, purchase insurance on a group basis; referred to Commerce, Science & Transportation.

Nuclear. S. 912—Simpson (R.-Wyo.). Says the Nuclear Regulatory Commission does not have to hold public hearings on applications for amendments to licenses when no significant hazards are involved; referred to Environment & Public Works.

S. 913—Simpson (R.-Wyo.). Allows NRC to issue interim operating licenses for fuel loading, low-power operation, and testing of a nuclear reactor before hearings; referred to Environment & Public Works.

Records. S. 961—Bentsen (D.-Tex.). Sets a five-year statute of limitations on federal record-keeping requirements, except for those involving hazardous materials; referred to Judiciary.

Regulation. S. 890—Schmitt (R.-N.M.). Sets up procedures under which Congress would have 60 days to disapprove proposed agency rules; referred to Judiciary.

S. 1080—Laxalt (R.-Nev.). Mandates procedures requiring regulatory agencies to identify and evaluate the trade-offs inherent in any regulation; referred to Governmental Affairs, Judiciary.

Research. S. 881—Rudman (R.-N.H.). Requires agencies having R&D budget over $100 million to establish small business innovation research programs, modeled after NSF's; referred to Small Business.

Transportation. S. 960—Cannon (D.-Nev.). Sets forth methods for preventing and improving response to accidents involving hazardous materials; referred to Commerce, Science & Transportation.

Trade. S. 1150—Heinz (R.-Pa.). Provides that a country would no longer be eligible for generalized system of preference benefits for a product sector if its exports to the U.S. in that sector exceeded $250 million in one year; referred to Finance.

Products. S. 1155—Kasten (R.-Wis.). Encourages use of voluntary standards by the Consumer Product Safety Commission; referred to Commerce, Science & Transportation.

HOUSE

Business. H.R. 2892—Mottl (D.-Ohio). Prohibits any major petroleum producer, refiner, marketer from controlling any business in another industry; referred to Energy & Commerce, Judiciary.

Energy. H.R. 3236—Udall (D.-Ariz.). Provides for expedited and coordinated process for decisions on proposed nonnuclear energy facilities; referred to Energy & Commerce.

Environment. H.R. 2931—Levitas (D.-Ga.). Requires EPA to take into account economic and technological feasibility when deciding whether to approve state implementation plans; referred to Energy & Commerce.

H.R. 2957—Howard (D.-N.J.). Deletes prohibition on use of public treatment works grants for treating, storing, or conveying the flow of industrial users into treatment works; referred to Public Works & Transportation.

H.R. 3471—Broyhill (R.-N.C.). Makes major changes in Clean Air Act, including setting procedures for establishing scientific basis for ambient air quality standards, extends compliance deadlines, eliminates lowest achievable emission reduction requirements; referred to Energy & Commerce.

Health. H.R. 3163—Railsback (R.-Ill.). Provides for epidemiological study of persons exposed to the herbicide agent orange conducted by the National Academy of Sciences; referred to Energy & Commerce.

Materials. H.R. 2603—McDonald (D.-Ga.). Funds purchase of strategic materials for stockpiling; referred to Armed Services.

Minerals. H.R. 2826—Emerson (R.-Mo.). Calls for review of policy governing mineral leases on public lands; referred to Interior & Insular Affairs.

H.R. 3364—Santini (D.-Nev.). Creates Council on Minerals & Materials, calls for inventory of minerals on public lands, provides tax relief for mining industry; referred to Interior & Insular Affairs, Ways & Means.

Research. H.R. 3091—Lewis (R.-Calif.). Strengthens role of small businesses in federally funded R&D; referred to Small Business.

H.R. 3137—Brown (D.-Calif.). Establishes Institute for Information Policy & Research; referred to Science & Technology.

Science policy. H.R. 3441—Ritter (R.-Pa.). Establishes coordinated program under direction of Office of Science & Technology Policy, for improving use of risk analysis by federal agencies; referred to Science & Technology.

Taxes. H.R. 3288—Shannon (D.-Mass.). Provides 25% tax credit for increase in a firm's R&D spending in excess of expenditures for previous three years and for research funds given to universities; referred to Ways & Means.

Indiana tops in new graduates

There have been some changes at the top of the rankings of the largest producers of chemistry graduates in the U.S. After leading the pack for six years, the University of North Carolina, Chapel Hill, is no longer the largest producer of B.S. chemists. And, again after a six-year reign, the University of Illinois, Urbana-Champaign, has been bumped from the top of the list of producers of Ph.D. chemists.

These changes are apparent from data gleaned by C&EN from the latest annual report of ACS's Committee on Professional Training (CPT). This committee is the mechanism by which the society monitors undergraduate chemistry programs. The committee does not monitor graduate programs, but it does gather data on them. It also gathers data on chemical engineering programs. (The full text of the report, which covers the 1979–80 academic year, starts on page 38.)

For the latest ranking, Indiana University moves up from the second position in 1978–79 to become the largest producer of new B.S. chemistry graduates, with a total of 150. The University of North Carolina, Chapel Hill, drops into second place with a total of 136, down from 171 in 1978–79.

For the sixth consecutive year the University of California, San Diego, is the largest producer of certified B.S. chemistry graduates. Such graduates have completed a curriculum specified by CPT and are eligible immediately for ACS membership.

The new leading producer of Ph.D. chemistry graduates is the University of California, Berkeley, with a total of 58. This is up from 41 last year, when the school ranked third.

In recent years, no one school has dominated production of M.S. chemists. In the latest report, it is the turn of Yale University to top the list with a total of 37. This is up from 36 the previous year, when it was good enough for second place.

Purdue University retains its position as the largest producer of B.S. chemical engineers.

Michael Heylin, Washington

These schools had the most chemistry graduates, 1979–80

Total B.S. graduates

1.	Indiana U	150
2.	U of North Carolina, Chapel Hill	136
3.	U of Florida	114
3.	U of Pittsburgh	114
5.	U of Illinois, Urbana-Champaign	113
6.	U of Virginia	104
7.	U of California, Los Angeles	96
7.	Emory U	96
9.	U of South Florida	92
10.	U of California, San Diego	90
11.	Duke U	83
11.	Miami U	83
13.	U of Miami	77
14.	Cornell U	66
15.	U of Colorado, Boulder	65
16.	U of Michigan, Ann Arbor	62
16.	U of Puerto Rico, Rio Piedras	62
16.	St. Louis U	62
19.	U of California, Irvine	61
19.	U of Maryland	61
21.	State U of New York, Stony Brook	60
22.	California State U, Long Beach	55
23.	U of Delaware	54
24.	St. Olaf C	52
25.	U of Texas, Austin	51

Certified B.S. graduates

1.	U of California, San Diego	90
2.	Cornell U	68
3.	U of Michigan, Ann Arbor	62
4.	U of Pittsburgh	57
5.	U of Texas, Austin	51
6.	U of California, Berkeley	47
7.	Rutgers U, Rutgers C	43
8.	Massachusetts Inst. of Technology	38
9.	U of Illinois, Urbana-Champaign	36
10.	State U of New York, Albany	35
11.	U of California, Berkeley	34
11.	U of Colorado, Boulder	34
11.	Illinois State U	34
11.	Lehigh U	34
11.	Rensselaer Polytechnic Inst.	34
11.	State U of New York, Stony Brook	34
17.	U of North Carolina, Chapel Hill	33
18.	Indiana U	32
19.	U of Illinois, Chicago Circle	29
20.	U of Minnesota, Minneapolis	28
20.	San Jose State U	28
22.	Cincinnati U	26
22.	U of Delaware	26
22.	Holy Cross U	26
22.	Texas A&M U	26
22.	U of Washington	26

M.S. graduates

1.	Yale U	37
2.	Northwestern U	33
3.	U of California, San Diego	31
3.	Harvard U	31
5.	Lawrence U	28
6.	Cornell U	27
7.	Cincinnati U	26
7.	Columbia U	26
9.	U of California, Berkeley	21
9.	U of California, Riverside	21
9.	Ohio State U	21
12.	U of Illinois, Chicago Circle	20
12.	U of Illinois, Urbana-Champaign	20
12.	Purdue U	20
15.	U of California, Santa Barbara	19
15.	U of Texas, Austin	19
17.	Morehouse C	18
17.	Rochester U	18
19.	U of Pittsburgh	16
19.	Rensselaer Polytechnic Inst.	16
19.	U of Washington	16
19.	U of Wisconsin, Madison	16
23.	Lehigh U	14
23.	Polytechnic Inst. of New York	14
23.	Wright State U	14

Ph.D. graduates

1.	U of California, Berkeley	58
2.	U of Illinois, Urbana-Champaign	53
3.	Massachusetts Inst. of Technology	39
4.	Purdue U	39
5.	U of Wisconsin, Madison	32
6.	U of California, Los Angeles	31
7.	U of Texas, Austin	29
8.	Indiana U	26
8.	Iowa State U	26
8.	Ohio State U	26
11.	Texas A&M U	25
12.	California Inst. of Technology	23
12.	Michigan State U	23
14.	Cornell U	22
14.	U of Michigan, Ann Arbor	22
14.	Northwestern U	22
14.	Stanford U	22
18.	Harvard U	20
18.	State U of New York, Buffalo	20
20.	Duke U	18
20.	Pennsylvania State U	18
22.	Case Western Reserve	17
22.	Massachusetts Inst. of Technology	17
22.	U of Minnesota, Minneapolis	17
22.	U of North Carolina, Chapel Hill	17

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ACS Committee on Professional Training 1980 Annual Report

The number of bachelor's degree graduates in chemistry from schools whose undergraduate chemistry programs are approved by ACS decreased almost 3% in 1979–80 from the previous year, the first such decrease since 1972. The number of master's degrees from these departments decreased 1%, and the number of Ph.D. degrees rose 2%, the first increase in chemistry Ph.D.'s since 1975.

The percentage of baccalaureate graduates certified to ACS decreased slightly to 41% from the 42% reported in 1978–79 but is the same as reported the previous three years. (Certified graduates are those who have completed the curriculum specified by CPT and are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1979–80 by departments whose chemistry programs are ACS-approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering and Technology. (Note: These departments are not required to report their data to CPT, so the number of departments included in this listing varies from year to year.)

It is interesting to note that the number of bachelor's degrees in chemical engineering from the 109 AIChE-ABET-accredited departments that reported in 1980 increased 7% from the total reported by 112 departments the previous year, and that these 112 departments reported an expected further increase of 9% in 1980. During the five-year period from 1976 to 1980, the number of reported bachelor's degree graduates in chemical engineering from these schools increased 83%. At the graduate level, the number of chemical engineering master's degrees reported in 1979 rose 2% from the year before, and the number of Ph.D. degrees reported rose 3%, the first increase at this level since 1973.

It is also interesting to note that the percentages of women continue to rise at each degree level in both chemistry and chemical engineering. In the past five years, women chemistry graduates have increased from 21% to 28% of bachelor's degrees reported, from 22% to 25% of master's degrees, and from 12% to 18% of Ph.D. degrees. During the same span, women chemical engineering graduates increased from 8% to 19% of bachelor's degrees reported, from 4% to 10% of master's degrees, and from 2% to 4% of Ph.D. degrees.

As part of the committee's approval activities, programs at all ACS-approved departments normally are re-evaluated at five-year intervals. There were 558 colleges and universities on the approved list at the end of 1980, and the committee studied the chemistry programs at 151 of them during the year. Each involved

Summary of data from approved programs, 1976–80

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (total)	Certified graduates	Non-certified graduates	Number of schools	Grad-uates	Number of schools	Grad-uates
CHEMISTRY								
1976	528	9,916	4103	5813	322	1676	189	1622
1977	534	10,207	4219	5988	321	1688	189	1563
1978	547	10,350	4285	6065	323	1798	189	1532
1979	551	10,451	4424	6027	323	1716	188	1532
1980	554	10,170	4170	6000	324	1698	188	1561
CHEMICAL ENGINEERING[a]								
1976	120	—	2920	—	108	1001	101	320
1977	120	—	3282	—	115	1095	103	298
1978	119	—	4225	—	114	1109	98	251
1979	112	—	4977	—	107	951	92	237
1980	109	—	5348	—	105	974	88	243

a Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year. **Note:** Bachelor's degree projections for 1981: 554 chemistry departments report that they expect a total of 10,768 bachelor graduates with majors in chemistry during the 1980–81 academic year, and 109 chemical engineering departments report that they expect a total of 5853 bachelor graduates with majors in chemical engineering.

Committee members, 1980

J. Arthur Campbell, *Chairman*
Harvey Mudd College
Alice J. Cunningham
Agnes Scott College
Ernest L. Eliel
University of North Carolina, Chapel Hill
Patricia A. M. Figueras
Eastman Kodak Research Labs
Harry B. Gray
California Institute of Technology
C. David Gutsche
Washington University
Donald E. Jones
Western Maryland College
Jack H. Lunsford
Texas A&M University
Peter Lykos
Illinois Institute of Technology
Eli M. Pearce
Polytechnic Institute of New York
Melvin B. Robin
Bell Telephone Laboratories
Jere P. Segrest
University of Alabama, Birmingham
Harry S. Mosher (consultant)
Stanford University
Bonnie R. Blaser, *secretary*
Nancy B. Jackson, *staff associate*
American Chemical Society

Summary of totals from 1980 reports from approved programs

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, total	554	7360	2810	10,170
Certified		3018	1152	4,170
Noncertified		4342	1658	6,000
Masters	324	1279	419	1,698
Doctorates	188	1287	274	1,561
CHEMICAL ENGINEERING				
Bachelors, certified	109	4331	1017	5,348
Masters	105	875	99	974
Doctorates	88	233	10	243

a review of extensive documentary materials submitted by the department head describing the current status of the program. During 1980, six chemistry programs were newly approved by the committee, two approved programs were put on probation, three were removed from probation, and one was removed from the approved list.

The committee decided to include in the 1981 edition of the ACS Directory of Graduate Research those master's degree departments in chemistry and chemical engineering whose undergraduate programs are ACS-approved, or, in the case of the chemical engineering departments, AIChE-ABET-accredited, and which also require a master's thesis. Approximately 103 such departments agreed to be listed on this basis.

The committee also began the two- to three-year process of revising the criteria used to evaluate undergraduate programs in chemistry. ACS-approved departments and the ACS divisions were asked for their suggestions for this revision, and an open meeting was held to discuss these ideas at the ACS national meeting in August in Las Vegas. The committee plans to continue its contact with the approved departments and ACS divisions as the revision progresses.

As a result of its interest in why chemistry faculty members leave for other positions, especially nonacademic ones, the committee conducted a survey on faculty mobility in the past 10 years in the ACS-approved departments, and a report of this study was published in C&EN (Feb. 16, page 28). However, since there were no previous data to compare the results with, it was decided to continue the survey on a regular basis to better identify trends.

Chemical and chemical engineering degrees awarded by approved schools, 1979–80

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	6	2	3	—	—	—	—
Adelphi U	1	3	3	—	—	—	—
Agnes Scott C	2	0	—	—	—	—	—
Akron, U of	13	0	9	3	(e)	—	—
Alabama, U of							
University	7	9	2	2	26	3	1
Birmingham	0	17	3	0	—	—	—
Huntsville	5	5	1	—	—	—	—
Alaska, U of	3	0	3	—	—	—	—
Albion C	1	21	—	—	—	—	—
Albright C	8	9	—	—	—	—	—
Alfred U	10	0	—	—	—	—	—
Allegheny C	3	36	—	—	—	—	—
Alma C	2	7	—	—	—	—	—
American U	3	0	1	9	—	—	—
Amherst C	6	9	—	—	—	—	—
Andrews U	6	9	—	—	—	—	—
Antioch C	4	5	—	—	—	—	—
Appalachian State U	1	9	1	—	—	—	—
Arizona State U	24	14	3	8	29	7	0
Arizona, U of	23	15	12	11	31	7	1
Arkansas, U of							
Fayetteville	7	24	1	7	42	2	1
Little Rock	5	11	0	—	—	—	—
Ashland C	0	2	—	—	—	—	—
Auburn U	3	33	3	0	76	8	2
Augsburg C	1	13	—	—	—	—	—
Augustana C							
Rock Island, Ill.	1	12	—	—	—	—	—
Sioux Falls, S.D.	2	9	—	—	—	—	—
Austin C	0	2	—	—	—	—	—
Baldwin-Wallace C	4	5	—	—	—	—	—
Ball State C	8	2	6	—	—	—	—
Barnard C	2	16	—	—	—	—	—
Bates C	7	4	—	—	—	—	—
Baylor U	16	14	2	4	—	—	—
Beloit C	0	7	—	—	—	—	—
Bemidji State U	2	3	—	—	—	—	—
Birmingham-Southern C	0	12	—	—	—	—	—
Bloomsburg State C	3	2	—	—	—	—	—
Boston C	8	21	6	2	—	—	—
Boston U	6	19	4	2	—	—	—
Bowdoin C	0	23	—	—	—	—	—
Bowling Green State U	6	29	4	—	—	—	—
Bradley U	1	7	1	—	—	—	—
Brandeis U	0	25	7	6	—	—	—
Bridgeport, U of	5	0	3	—	—	—	—
Bridgewater State C	3	6	—	—	—	—	—
Brigham Young U	22	13	2	4	38	9	2
Brown U	1	20	3	13	—	—	—
Bryn Mawr C	16	0	1	2	—	—	—
Bucknell U	5	12	6	—	29	0	—
Butler U	2	12	1	—	—	—	—
California Institute of Tech	8	4	5	23	13	5	10
California Polytechnic State U	11	21	5	—	—	—	—
California State C							
Bakersfield	3	5	—	—	—	—	—
San Bernardino	0	2	—	—	—	—	—
Stanislaus	4	2	—	—	—	—	—
California State Polytechnic U	16	0	—	—	(e)	—	—
California State U							
Chico	0	10	—	—	—	—	—
Dominguez Hills	9	9	—	—	—	—	—
Fresno	6	10	3	—	—	—	—
Fullerton	9	9	3	—	—	—	—
Hayward	13	17	3	—	—	—	—
Long Beach	17	38	8	—	—	—	—
Los Angeles	12	0	8	—	—	—	—
Northridge	12	13	2	—	—	—	—
Sacramento	6	14	6	—	—	—	—
California, U of							
Berkeley	47	1	21	58	139	20	12
Davis	25	10	8	9	58	10	2
Irvine	12	49	7	7	—	—	—
Los Angeles	34	64	11	31	—	—	—
Riverside	14	1	21	9	—	—	—
San Diego	90	0	31	16	—	—	—
Santa Barbara	22	2	19	14	22	5	0
Santa Cruz	17	8	7	4	—	—	—
Calvin C	10	9	—	—	—	—	—
Canisius C	5	0	—	—	—	—	—
Capital U	5	3	—	—	—	—	—
Carleton C	0	28	—	—	—	—	—
Carnegie-Mellon U	25	2	6	5	(e)	—	—
Carroll C	5	2	—	—	—	—	—
Carthage C	2	3	—	—	—	—	—
Case Western Reserve U	6	40	3	17	(e)	—	—
Catholic U of America	6	5	5	4	10	3	0
Centenary C of Louisiana	0	2	—	—	—	—	—
Central C	0	7	—	—	—	—	—
Central Connecticut State C	14	0	1	—	—	—	—
Central Florida, U of	22	0	5	—	—	—	—
Central Michigan U	4	10	4	—	—	—	—
Central State U							
Wilberforce, Ohio	4	1	—	—	—	—	—
Edmond, Okla.	0	9	—	—	—	—	—
Charleston, C of	8	6	—	—	—	—	—
Chatham C	2	2	—	—	—	—	—
Chicago, U of	12	21	3	16	—	—	—
Cincinnati, U of	26	0	26	15	74	11	1
Citadel, The	3	9	—	—	—	—	—
City U of New York				11			
Brooklyn C	0	47	0	—	—	—	—
City C	0	26	3	—	24	4	2
Herbert H. Lehman C	12	1	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Hunter C	1	6	0	—	—	—	—
Queens C	10	28	2	—	—	—	—
Clarion State C	8	2	—	—	—	—	—
Clark U	9	8	2	0	—	—	—
Clarkson C of Tech	7	0	4	2	89	11	5
Clemson U	10	2	1	2	49	5	0
Cleveland State U	23	0	8	4	49	4	3
Coe C	1	3	—	—	—	—	—
Colby C	0	5	—	—	—	—	—
Colgate U	0	12	—	—	—	—	—
Colorado C	2	10	—	—	—	—	—
Colorado School of Mines	8	0	5	2	72	10	7
Colorado State U	14	14	3	5	—	—	—
Colorado, U of							
Boulder	34	31	4	13	62	12	0
Denver	2	7	8	—	—	—	—
Columbia U	0	50	26	11	48	24	5
Concordia C	3	10	—	—	—	—	—
Connecticut, U of	14	29	5	3	50	5	0
Cooper Union[a]	—	—	—	—	(e)	—	—
Cornell C	0	14	—	—	—	—	—
Cornell U	68	0	27	22	66	5	3
Dartmouth C	0	22	2	6	—	—	—
David Lipscomb C	4	16	—	—	—	—	—
Davidson C	8	2	—	—	—	—	—
Dayton, U of	11	6	5	—	49	3	—
Delaware State C	1	1	—	—	—	—	—
Delaware, U of	26	28	11	6	56	14	10
Delaware Valley C of Science & Agriculture	4	0	—	—	—	—	—
Delta State U	3	10	2	—	—	—	—
Denison U	3	8	—	—	—	—	—
Denver, U of	7	10	5	6	—	—	—
DePaul U	2	8	5	—	—	—	—
DePauw U	5	13	—	—	—	—	—
Detroit, U of	8	4	6	4	(e)	—	—
Dickinson C	0	11	—	—	—	—	—
Drake U	2	2	2	—	—	—	—
Drew U	1	9	—	—	—	—	—
Drexel U	9	3	10	4	58	2	0
Duke U	15	68	2	18	—	—	—
Duquesne U	0	8	9	4	—	—	—
Earlham C	2	6	—	—	—	—	—
East Carolina U	3	21	1	—	—	—	—
East Stroudsburg State C	4	24	—	—	—	—	—
East Tennessee State U	7	4	4	—	—	—	—
East Texas State U	2	7	6	—	—	—	—
Eastern Illinois U	11	6	1	—	—	—	—
Eastern Kentucky U	1	7	1	—	—	—	—
Eastern Michigan U	5	15	9	—	—	—	—
Elizabethtown C	7	12	—	—	—	—	—
Elmhurst C	1	12	—	—	—	—	—
Emory U	2	96	9	3	—	—	—
Emporia State U	7	2	1	—	—	—	—
Evansville, U of	4	6	—	—	—	—	—
Fairfield U	12	4	—	—	—	—	—
Fairleigh Dickinson U							
Rutherford	6	3	3	—	—	—	—
Teaneck	19	0	7	—	—	—	—
Fisk U	8	0	1	—	—	—	—
Florida Atlantic U	4	15	4	—	—	—	—
Florida State U	5	27	3	9	—	—	—
Florida, U of	13	101	9	16	44	5	0
Fordham U	3	3	2	9	—	—	—
Fort Lewis C	0	14	—	—	—	—	—
Franklin and Marshall C	16	8	—	—	—	—	—
Furman U	2	11	2	—	—	—	—
Geneva C	3	5	—	—	—	—	—
George Mason U	8	4	—	—	—	—	—
George Washington U	6	15	3	1	—	—	—
Georgetown U	19	0	3	3	—	—	—
Georgia Institute of Tech	23	0	6	14	(e)	—	—
Georgia State U	3	4	4	—	—	—	—
Georgia, U of	2	39	11	13	—	—	—
Gettysburg C	4	8	—	—	—	—	—
Glassboro State C[b]	—	—	—	—	—	—	—
Gonzaga U	3	7	—	—	—	—	—
Goucher C	0	10	—	—	—	—	—
Grand Valley State C	1	6	—	—	—	—	—
Grinnell C	3	23	—	—	—	—	—
Gustavus Adolphus C	9	16	—	—	—	—	—
Hamilton C	0	9	—	—	—	—	—
Hamline U	4	3	—	—	—	—	—
Hampden-Sydney C	5	5	—	—	—	—	—
Hampton Institute	1	8	—	—	—	—	—
Hartford, U of	4	7	0	—	—	—	—
Hartwick C	1	2	—	—	—	—	—
Harvard U	0	22	31	20	—	—	—
Harvey Mudd C	16	0	—	—	—	—	—
Haverford C	11	13	—	—	—	—	—
Hawaii, U of	18	8	5	6	—	—	—
Hiram C	7	11	—	—	—	—	—
Hobart & William Smith C	0	11	—	—	—	—	—
Hofstra U	3	7	—	—	—	—	—
Hollins C	1	0	—	—	—	—	—
Holy Cross, C of The	26	20	0	—	—	—	—
Hope C	11	20	—	—	—	—	—
Houston, U of	8	0	6	10	34	14	7
Howard U	2	30	2	7	14	—	—
Humboldt State U	4	1	—	—	—	—	—
Idaho State U	2	4	2	—	—	—	—
Idaho, U of	6	5	7	3	22	16	1
Illinois Benedictine C	13	0	—	—	—	—	—
Illinois Institute of Tech	9	0	4	1	(e)	—	—
Illinois State U	34	1	8	—	—	—	—
Illinois, U of							
Chicago Circle	29	19	20	13	(e)	—	—
Urbana-Champaign	36	77	20	53	138	13	6
Illinois Wesleyan U	0	10	—	—	—	—	—
Indiana State U	9	3	5	—	—	—	—
Indiana U	32	118	6	26	—	—	—
Indiana U of Pennsylvania	8	2	6	—	—	—	—
Indiana U, South Bend	3	2	—	—	—	—	—
Indiana U-Purdue U							
Fort Wayne	3	3	—	—	—	—	—
Indianapolis	2	26	4	—	—	—	—
Iowa State U	10	4	8	26	68	11	8
Iowa, U of	8	2	7	7	7	9	4
Ithaca C	10	2	—	—	—	—	—
Jackson State U	8	2	0	0	—	—	—
James Madison U[b]	—	—	—	—	—	—	—
John Carroll U	6	13	3	—	—	—	—
Johns Hopkins U	13	0	7	10	—	—	—
Juniata C	7	9	—	—	—	—	—
Kalamazoo C	7	14	—	—	—	—	—
Kansas State U	2	7	4	5	18	6	0
Kansas, U of	11	32	5	8	43	10	1
Kearney State C	0	3	—	—	—	—	—
Kent State U	8	13	4	3	—	—	—
Kentucky, U of	5	8	8	2	54	9	2
Kenyon C	10	2	—	—	—	—	—
King's C	9	1	—	—	—	—	—
Knox C	2	16	—	—	—	—	—
Lafayette C	4	7	—	—	29	—	—
Lake Forest C	2	5	—	—	—	—	—
Lamar C	5	0	1	—	45	10	0
LaSalle C	9	3	—	—	—	—	—
Lawrence U	3	2	28	6	—	—	—
Lebanon Valley C	8	5	—	—	—	—	—
Lehigh U	34	0	14	6	86	17	2
LeMoyne C	8	0	—	—	—	—	—
Lincoln U	0	3	—	—	—	—	—
Long Island U							
Conolly C	2	1	3	—	—	—	—
C. W. Post C	3	3	—	—	—	—	—
Loras C	2	4	—	—	—	—	—
Louisiana State U							
Baton Rouge	4	4	3	9	81	13	2
Shreveport	5	0	—	—	—	—	—
Louisiana Tech U	1	6	2	—	32	1	1
Louisville, U of	4	21	0	5	—	17	1
Lowell, U of	11	0	4	1	29	2	—
Loyola C	8	0	—	—	—	—	—
Loyola Marymount U	5	0	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Loyola U	1	0	—	—	—	—	—
Loyola U of Chicago	13	9	3	1	—	—	—
Luther C	3	8	—	—	—	—	—
Macalester C	3	15	—	—	—	—	—
MacMurray C	0	7	—	—	—	—	—
Maine, U of	6	3	2	0	28	3	0
Manhattan C[c]	22	3	—	—	68	29	—
Manhattanville C	1	0	—	—	—	—	—
Mankato State U	1	13	1	—	—	—	—
Marietta C	4	0	—	—	—	—	—
Marist C	0	1	—	—	—	—	—
Marquette U	16	3	6	3	—	—	—
Marshall U	2	19	2	—	—	—	—
Maryland, U of	2	59	6	15	(e)	—	—
Maryland Baltimore County, U of	10	0	2	0	—	—	—
Massachusetts Institute of Tech	38	0	4	39	(e)	—	—
Massachusetts, U of	12	7	8	17	46	8	2
McMurry C	3	7	—	—	—	—	—
McNeese State U	2	3	0	—	—	—	—
Memphis State U	2	8	1	2	—	—	—
Merrimack C	10	0	—	—	—	—	—
Metropolitan State C	10	4	—	—	—	—	—
Miami U	17	66	8	3	—	—	—
Miami, U of	2	75	2	2	—	—	—
Michigan State U	13	7	7	23	91	8	1
Michigan Tech U	20	0	4	0	59	7	—
Michigan, U of							
Ann Arbor	62	0	10	22	108	19	1
Dearborn	15	5	—	—	—	—	—
Flint	1	10	—	—	—	—	—
Middle Tennessee State U	1	36	7	—	—	—	—
Middlebury C	0	5	—	—	—	—	—
Midwestern State U	2	9	—	—	—	—	—
Millersville State C	4	3	—	—	—	—	—
Millsaps C	5	22	—	—	—	—	—
Minnesota, U of							
Minneapolis	28	7	8	17	(e)	—	—
Duluth	11	11	5	—	—	—	—
Mississippi C	0	11	—	—	—	—	—
Mississippi State U	2	7	2	3	31	1	1
Mississippi, U of	2	31	2	2	18	10	0
Missouri, U of							
Columbia	14	6	3	2	50	13	0
Kansas City	5	16	3	8	—	—	—
Rolla	14	0	10	0	83	6	2
St. Louis	17	4	4	3	—	—	—
Monmouth C	1	5	—	—	—	—	—
Montana State U	2	5	3	3	57	3	0
Montana, U of	3	7	0	0	—	—	—
Montclair State C	9	15	6	—	—	—	—
Moorhead State U	1	1	0	—	—	—	—
Moravian C	2	7	—	—	—	—	—
Morehouse C[d]	1	7	18	—	—	—	—
Morgan State U	10	13	—	—	—	—	—
Mount Holyoke C	0	12	1	0	—	—	—
Mount Saint Vincent, C of[c]	1	0	—	—	—	—	—
Muhlenberg C	6	24	—	—	—	—	—
Murray State U	2	10	3	—	—	—	—
Muskingum C	0	7	—	—	—	—	—
Nebraska, U of							
Lincoln	7	14	3	14	23	1	—
Omaha	4	3	—	—	—	—	—
Nebraska Wesleyan U	3	4	—	—	—	—	—
Nevada, U of							
Las Vegas	0	3	—	—	—	—	—
Reno	2	4	8	3	—	—	—
New Hampshire, U of	7	6	3	10	42	3	0
New Jersey Institute of Tech[a]	—	—	—	—	74	13	2
New Mexico Highlands U	1	1	2	—	—	—	—
New Mexico Institute of Mining & Tech	4	0	3	—	—	—	—
New Mexico State U	6	4	3	5	36	4	—
New Mexico, U of	12	6	9	0	25	5	0
New Orleans, U of	6	5	2	6	—	—	—
New York U	7	21	12	9	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
North Alabama, U of	10	12	—	—	—	—	—
North Carolina A&T State U	3	0	3	—	—	—	—
North Carolina Central U	0	1	2	—	—	—	—
North Carolina State U	25	4	1	3	52	10	5
North Carolina, U of							
Chapel Hill	33	103	7	17	—	—	—
Charlotte	4	7	2	—	—	—	—
Greensboro	11	2	2	—	—	—	—
Wilmington	5	10	—	—	—	—	—
North Dakota State U	2	4	4	2	—	—	—
North Dakota, U of	4	6	3	2	23	5	—
North Texas State U	4	11	5	4	—	—	—
Northeast Louisiana U	6	0	1	—	—	—	—
Northeastern U	12	0	11	5	(e)	—	—
Northern Arizona U	3	34	2	—	—	—	—
Northern Colorado, U of	8	9	1	—	—	—	—
Northern Illinois U	9	11	6	4	—	—	—
Northern Iowa, U of	4	7	2	—	—	—	—
Northern Michigan U	2	14	2	—	—	—	—
Northwest Missouri State U	2	5	—	—	—	—	—
Northwestern State U of Louisiana	1	4	0	—	—	—	—
Northwestern U	19	22	33	22	48	15	8
Norwich U	3	1	—	—	—	—	—
Notre Dame, U of	4	11	8	8	59	7	3
Oakland U	10	11	1	—	—	—	—
Oberlin C	6	22	—	—	—	—	—
Occidental C	8	5	—	—	—	—	—
Ohio Northern U	2	7	—	—	—	—	—
Ohio State U	17	6	21	26	55	9	2
Ohio U	12	2	1	4	14	2	0
Ohio Wesleyan U	1	6	—	—	—	—	—
Oklahoma State U	1	5	2	6	46	12	2
Oklahoma, U of	6	15	5	5	52	12	4
Old Dominion U	4	9	5	—	—	—	—
Oregon State U	9	0	7	9	56	8	0
Oregon, U of	6	16	4	11	—	—	—
Pace U	3	1	—	—	—	—	—
Pacific Lutheran U	3	20	—	—	—	—	—
Pacific, U of The	2	26	0	0	—	—	—
Pennsylvania State U	18	27	10	18	126	10	5
Pennsylvania, U of	10	15	4	16	34	22	6
Philadelphia C of Pharmacy & Science	2	0	4	2	—	—	—
Philadelphia C of Textiles & Science	6	2	—	—	—	—	—
Pittsburg State U	4	7	4	—	—	—	—
Pittsburgh, U of	57	57	16	14	90	17	3
Polytechnic Institute of New York	4	0	14	11	44	15	3
Pomona C	11	7	—	—	—	—	—
Portland State U	4	14	3	0	—	—	—
Pratt Institute[a]	—	—	—	—	9	—	—
Princeton U	12	3	10	14	57	5	8
Providence C	4	4	2	0	—	—	—
Puerto Rico, U of							
Mayaguez	12	19	5	—	63	1	—
Rio Piedras	13	49	6	6	—	—	—
Puget Sound, U of	7	13	2	—	—	—	—
Purdue U	14	20	20	39	179	21	18
Purdue U, Calumet	4	0	—	—	—	—	—
Randolph-Macon Woman's C	2	0	—	—	—	—	—
Redlands, U of	0	3	—	—	—	—	—
Reed C	11	3	—	—	—	—	—
Regis C	0	4	—	—	—	—	—
Rensselaer Polytechnic Institute	34	0	16	7	81	8	0
Rhode Island, U of	0	1	7	4	16	6	0
Rice U	5	1	2	4	32	23	2
Richmond, U of	3	19	0	—	—	—	—
Rider C	4	0	—	—	—	—	—
Ripon C	(e)	—	—	—	—	—	—
Roanoke C	4	5	—	—	—	—	—
Rochester Institute of Tech	5	0	8	—	—	—	—
Rochester, U of	6	9	18	10	33	4	2
Rollins C	0	4	—	—	—	—	—
Roosevelt U	3	0	13	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Rose-Hulman Institute of Tech	6	0	—	—	(e)	—	—
Russell Sage C	3	2	—	—	—	—	—
Rutgers U	—	—	9	9	(e)	—	—
Douglass C	25	0	—	—	—	—	—
Rutgers C	43	3	—	—	—	—	—
Newark C of Arts & Sciences	12	10	12	5	—	—	—
Saginaw Valley State C	4	5	—	—	—	—	—
St. Anselm's C	4	5	—	—	—	—	—
St. Cloud State U	2	8	—	—	—	—	—
St. John Fisher C	7	4	—	—	—	—	—
St. John's U	9	1	5	0	—	—	—
St. Joseph C	4	2	2	—	—	—	—
St. Joseph's U	12	15	8	—	—	—	—
St. Lawrence U	9	19	—	—	—	—	—
St. Louis U	8	54	4	1	—	—	—
St. Mary's C	5	7	—	—	—	—	—
St. Olaf C	6	46	—	—	—	—	—
St. Peter's C	2	2	—	—	—	—	—
St. Thomas, C of	2	8	—	—	—	—	—
Sam Houston State U	13	2	3	—	—	—	—
San Diego State U	20	0	7	1	—	—	—
San Francisco State U	7	23	5	—	—	—	—
San Francisco, U of	7	6	1	—	—	—	—
San Jose State U	28	19	5	—	16	6	—
Santa Clara, U of	5	9	—	—	—	—	—
Scranton, U of	1	26	7	—	—	—	—
Seattle U	4	8	—	—	—	—	—
Seton Hall U	13	0	7	4	—	—	—
Shippensburg State C	6	2	3	—	—	—	—
Siena C	11	0	—	—	—	—	—
Simmons C	2	4	—	—	—	—	—
Skidmore C	1	12	—	—	—	—	—
Slippery Rock State C	1	4	—	—	—	—	—
Smith C	1	7	0	0	—	—	—
Sonoma State U	3	5	—	—	—	—	—
South Carolina, U of	3	27	6	13	26	6	1
South Dakota School of Mining & Tech	8	0	2	—	28	7	—
South Dakota State U	3	25	2	—	—	—	—
South Dakota, U of	2	18	4	—	—	—	—
South Florida, U of	19	73	3	3	12	2	0
Southeast Missouri State U	0	5	—	—	—	—	—
Southeastern Massachusetts U	7	2	0	—	—	—	—
Southern California, U of	8	7	5	15	(e)	—	—
Southern Illinois U							
Carbondale	8	14	3	5	—	—	—
Edwardsville	5	10	4	—	—	—	—
Southern Methodist U	16	11	2	—	—	—	—
Southern Mississippi, U of	6	10	1	2	—	—	—
Southern Oregon State C	3	9	—	—	—	—	—
Southern U and A&M C	7	1	0	—	—	—	—
Southwest Missouri State U	0	24	—	—	—	—	—
Southwest State U	1	5	—	—	—	—	—
Southwest Texas State U	7	1	6	—	—	—	—
Southwestern at Memphis	3	2	—	—	—	—	—
Southwestern Louisiana, U of	2	14	1	—	16	6	—
Southwestern Oklahoma State U	1	17	—	—	—	—	—
Stanford U	15	21	2	22	31	15	10
State U of New York							
Albany	35	0	3	3	—	—	—
Binghamton	8	31	2	4	—	—	—
Buffalo	14	26	8	20	73	13	5
Stony Brook	34	26	6	8	—	—	—
C at Brockport	4	7	—	—	—	—	—
C at Buffalo	9	1	1	—	—	—	—
C at Cortland	2	7	—	—	—	—	—
C at Fredonia	4	5	6	—	—	—	—
C at Geneseo	5	0	0	—	—	—	—
C at New Paltz	7	0	1	—	—	—	—
C at Oneonta	0	15	0	—	—	—	—
C at Oswego	18	4	3	—	—	—	—
C at Plattsburgh	7	4	3	—	—	—	—
C at Potsdam	0	14	—	—	—	—	—
Stephen F. Austin State U	0	9	0	—	—	—	—
Stetson U	5	5	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
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	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Stevens Institute of Tech	11	3	8	1	—	—	—
Suffolk U	2	1	—	—	—	—	—
Susquehanna U	1	1	—	—	—	—	—
Swarthmore C	5	10	—	—	—	—	—
Syracuse U	8	15	1	4	24	6	3
Temple U	6	11	7	5	—	—	—
Tennessee Tech U	2	13	1	—	24	7	—
Tennessee, U of							
Knoxville	7	13	8	9	(e)	—	—
Chattanooga	7	15	—	—	—	—	—
Martin	4	8	—	—	—	—	—
Texas A&I U	2	0	1	—	18	15	—
Texas A&M U	26	12	8	25	156	12	5
Texas Christian U	4	7	1	3	—	—	—
Texas Southern U	17	0	5	—	—	—	—
Texas Tech U	12	10	9	7	(e)	—	—
Texas, U of							
Arlington	11	11	4	—	—	—	—
Austin	51	0	19	29	100	24	7
Dallas	6	0	1	—	—	—	—
El Paso	7	0	5	—	—	—	—
Texas Woman's U	2	0	0	0	—	—	—
Thiel C	3	9	—	—	—	—	—
Thomas More C	4	2	—	—	—	—	—
Toledo, U of	2	20	3	1	21	3	3
Towson State U	1	8	—	—	—	—	—
Trenton State C	6	1	—	—	—	—	—
Trinity C	9	9	0	—	—	—	—
Trinity U	2	3	0	—	—	—	—
Tri-State U[a]	—	—	—	—	(e)	—	—
Tufts U	0	38	5	2	41	8	0
Tulane U of Louisiana	0	6	1	3	(e)	—	—
Tulsa, U of	5	0	—	—	31	7	0
Tuskegee Institute	1	3	2	—	—	—	—
Union C	1	6	2	—	—	—	—
U.S. Air Force Academy	6	2	—	—	—	—	—
U.S. Naval Academy	18	0	—	—	—	—	—
Ursinus C	10	14	—	—	—	—	—
Utah State U	7	0	0	4	—	—	—
Utah, U of	4	30	4	14	30	8	5
Valparaiso U	3	27	—	—	—	—	—
Vanderbilt U	5	34	2	7	45	6	1
Vassar C	2	2	0	—	—	—	—
Vermont, U of	20	0	0	5	—	—	—
Villanova U	11	0	8	2	29	3	—
Virginia Commonwealth U	5	34	3	1	—	—	—
Virginia Military Institute	12	0	—	—	—	—	—
Virginia Polytechnic Institute & State U	8	14	11	9	86	5	0
Virginia, U of	14	90	1	7	45	18	0
Wabash C	9	4	—	—	—	—	—
Wagner C	2	6	—	—	—	—	—
Wake Forest U	0	24	2	0	—	—	—
Washburn U of Topeka	7	2	—	—	—	—	—
Washington C	8	0	—	—	—	—	—
Washington and Jefferson C	9	17	—	—	—	—	—
Washington and Lee U	0	11	—	—	—	—	—
Washington State U	8	16	4	10	32	6	1
Washington U	3	12	5	5	48	17	3
Washington, U of	26	20	16	16	88	27	6
Wayne State U	13	28	10	8	36	14	2
Waynesburg C	3	1	—	—	—	—	—
Weber State C	5	5	—	—	—	—	—
Wellesley C	6	22	—	—	—	—	—
Wells C	0	3	—	—	—	—	—
Wesleyan U	2	16	0	6	—	—	—
West Chester State C	7	14	1	—	—	—	—
West Florida, U of	17	3	—	—	—	—	—
West Texas State U	0	9	1	—	—	—	—
West Virginia Institute of Tech	3	1	—	—	15	0	—
West Virginia State C	0	4	—	—	—	—	—
West Virginia U	7	34	4	6	43	10	2
Western Illinois U	3	4	3	—	—	—	—
Western Kentucky U	3	11	3	—	—	—	—
Western Maryland C	1	11	—	—	—	—	—
Western Michigan U	1	27	4	1	—	—	—
Western New England C	0	3	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Western Washington U	8	14	2	—	—	—	—
Westminster C	0	7	—	—	—	—	—
Wheaton C (Illinois)	2	25	—	—	—	—	—
Wheaton C (Massachusetts)	3	8	—	—	—	—	—
Wheeling C	0	0	—	—	—	—	—
Whitman C	3	8	—	—	—	—	—
Whittier C	3	9	—	—	—	—	—
Wichita State U	9	9	5	2	—	—	—
Widener U	2	0	—	—	—	—	—
Wilkes C	3	2	—	—	—	—	—
Willamette U	2	4	—	—	—	—	—
William and Mary, C of	24	11	2	—	—	—	—
William Paterson C of New Jersey[b]							
Williams C	4	34	—	—	—	—	—
Wisconsin, U of							
Eau Claire	3	9	—	—	—	—	—
Green Bay	0	4	—	—	—	—	—
La Crosse	7	14	—	—	—	—	—
Madison	7	18	16	32	86	18	6
Milwaukee	3	22	8	1	—	—	—
Oshkosh	4	8	1	—	—	—	—
Parkside	8	10	—	—	—	—	—
Platteville	2	4	—	—	—	—	—
River Falls	6	6	—	—	—	—	—
Stevens Point	4	5	—	—	—	—	—
Superior	1	4	—	—	—	—	—
Wittenberg U	3	13	—	—	—	—	—
Wooster, C of	11	21	—	—	—	—	—
Worcester Polytechnic Institute	7	15	0	0	82	11	1
Wright State U	15	19	14	—	—	—	—
Wyoming, U of	8	4	3	3	28	7	0
Xavier U (Ohio)	3	9	2	—	—	—	—
Xavier U of Louisiana	2	10	—	—	—	—	—
Yale U	18	1	37	14	—	—	—
Youngstown State U	9	26	6	—	27	—	—
TOTALS	**4170**	**6000**	**1698**	**1561**	**5348**	**974**	**243**

a Listed on basis of accreditation by AIChE-ABET. b Added in 1980. c The chemistry programs at Mount Saint Vincent College and Manhattan College are integrated into a combined department with all instruction in chemistry located at Manhattan College. d Master's degrees given by Atlanta University. e Data not submitted. **Note:** For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column.

Official reports from the Atlanta meeting

The major actions taken by the ACS Board and Council during the society's national meeting in Atlanta this spring have been reported in C&EN, April 20, page 57.

SOCIETY COMMITTEE REPORTS

Budget & Finance

The committee is operating in 1981 with a basic structure of three subcommittees—on Policy, on Budgets & Programs, and on the Financial Impact of Constitution & Bylaw Amendments. The committee received the auditor's report that in the society's 1980 financial statements its position has been fairly stated in conformity with generally accepted accounting principles. The committee will work with the Committee on Membership Affairs to develop priority groupings for all dues-supported programs in 1982 so that a more meaningful budget may be developed for 1982. The committee voted to recommend to the board of directors that the dues increase for 1982 be $7.00. The committee approved funding for the Hildebrand Centennial, honoring the 100th birthday of ACS past-president Joel Henry Hildebrand, and approved a new program request for academic fellowships.

Clayton F. Callis, *chairman*

Chemical Abstracts Service

The committee elected James D. D'Ianni vice-chairman and secretary for 1981. Reports were received from two subcommittees and task forces; two new task forces were appointed. The achievement of 1980 goals was discussed and eight objectives for CAS in 1981 were proposed. Two services will be discontinued—REG/CAN and CA BIBLIO. In addition, synonyms will be added to the Registry Profile Service Use Class 1. A status report on CAS's Publications & Services Division was presented, and reports from the International Agreement Associates (Centre National de l'Information Chimique and Internationale Dokumentationsgesellschaft für Chemie m.b.H) were received. The 1980 actual financial results and the interim 1981 financial status report were reviewed. A status report on contracts and grants and the real property tax exemption case were reviewed. Also, a new pricing and grants policy for printed *CA* was approved.

Paul V. Smith Jr., *chairman*

Chemical Education

At its inaugural session the committee endorsed a proposal for an academic fellowships program that would provide partial financial support for college teachers who wish to attend ACS Short Courses; approved two documents prepared by a special ad interim task force expressing concern about fiscal 1982 funding for the NSF Science Education Directorate—one a committee "Comment" for the April 6 C&EN and the other a proposed ACS policy statement; endorsed the proposed conversion of the Project SEED Subcommittee to a new "other" committee of the council; approved for outside funding a proposal to develop a new high school chemistry curriculum for the general student; agreed to recommend to the board and council that ACS pay special attention to the forthcoming 250th anniversary of the birth of Joseph Priestley; and established, and then elected Alan L. McClelland to, the office of vice chairman.

Stanley Kirschner, *chairman*

Publications

The committee reviewed the 1980 financial performance of the Books & Journals Division, C&EN, and *SciQuest*, and approved 1982 subscription prices for ACS publications. At present, the committee plans to remove page charges in 1982 from all journals except *Biochemistry* and the *Journal of Agricultural and Food Chemistry*. The final decision to retain or drop page charges will be made in December 1981 and will be based on financial forecasts for 1982.

The first issue of *Organometallics*, the society's first new journal in 14 years, will be published in January 1982. Dietmar Seyferth and Richard R. Schrock are the journal's editor and associate editor, respectively.

A special subcommittee on *SciQuest* continues to monitor the magazine's progress against its five-year plan; the subcommittee's report is due in December. Meanwhile *SciQuest's* circulation continues to rise.

The on-line primary journal data base experiment is being expanded to include all 1980 ACS research journals (except the January–June issues of *JACS*) and the 1976–80 issues of the *Journal of Medicinal Chemistry*; the data base will be updated every two weeks. Several hundred volunteers will help with the experiment.

Gordon L. Nelson, *chairman*

BOARD COMMITTEE REPORTS

Standing Committees

Grants & Awards

The committee recommended that the board of directors accept the offer of Phillips Petroleum Co. to sponsor an ACS Award in Applied Polymer Science, a successor to the ACS Award in the Chemistry of Plastics & Coatings sponsored by Borden Foundation Inc. First presentation of the new award will be in 1983. Also approved were a change from four to five local section size categories for the ACS Award for Outstanding Performance by Local Sections and a change in the site for presentation of the 1982 Frederic Stanley Kipping Award in Organosilicon Chemistry to the 14th ACS Central Regional Meeting, Midland, Mich., June 16–18, 1982.

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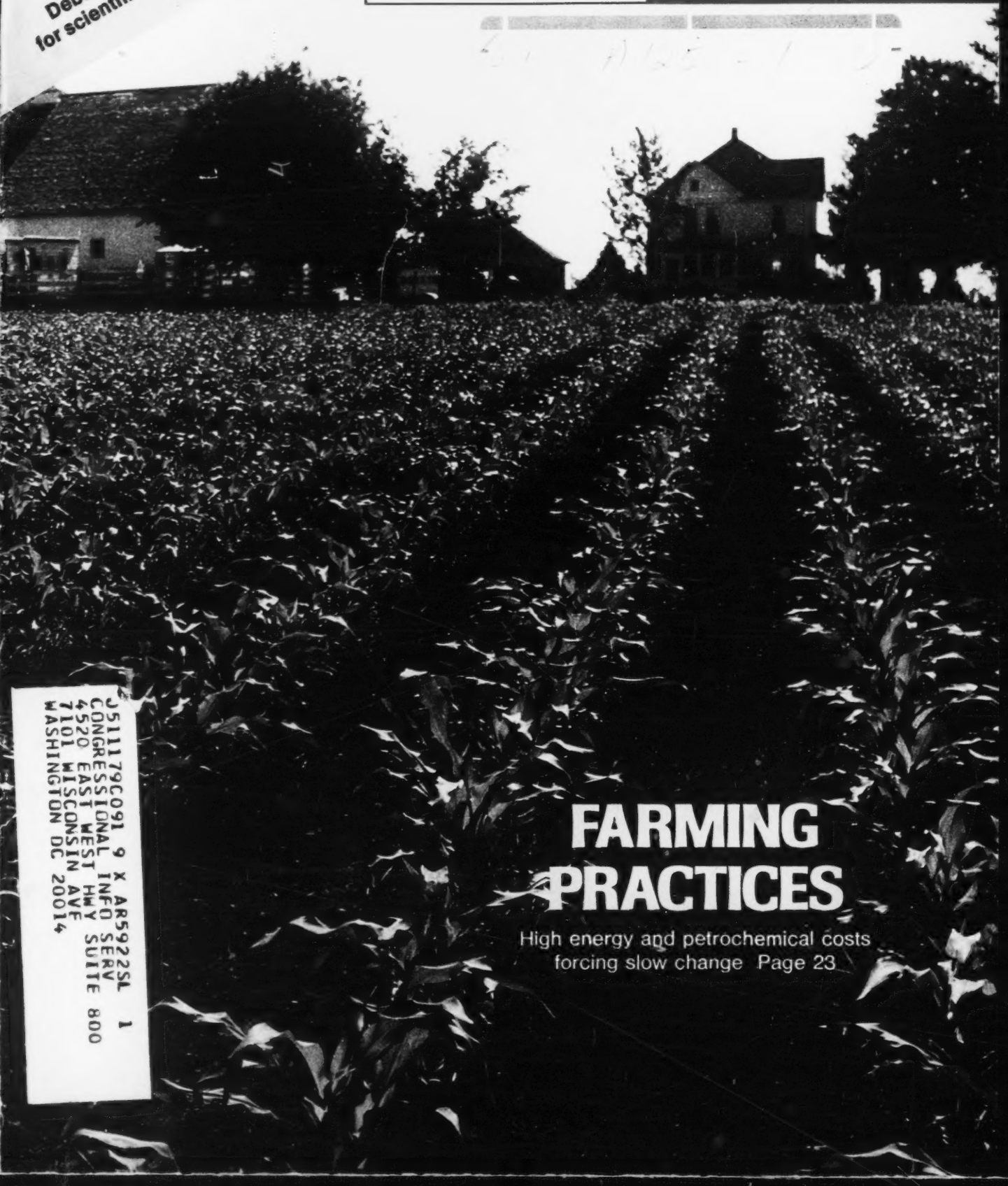
Chemical & Engineering NEWS
June 1, 1981

Debt financing an alternative for scientific equipment Page 20



FARMING PRACTICES

High energy and petrochemical costs forcing slow change Page 23

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Chemical profitability sagged in 1980

Profit margins, return on investment, return on assets, and return on equity all dropped last year for U.S. chemical firms

William J. Storck
C&EN, New York

Profitability for U.S. chemical companies fell on all fronts in 1980.

- Profit margins in 1980 fell to 6.1% from 6.6% in 1979.
- Return on investment fell to 5.0% from 5.4%.
- Return on assets fell to 6.9% from 7.3%.
- Return on equity dropped to 14.5% from 15.6%.

It is no wonder that profitability took its lumps, though, because chemical earnings rose only 3% in 1980 from 1979. Sales, investment, assets, and equity all increased faster than that.

In its profitability decline, the U.S. chemical industry was in line with all U.S. manufacturing industries, which, according to government figures, also experienced decreased returns on sales, investment, assets, and equity in 1980 from 1979.

The top 10 in overall profitability

1 Freeport-McMoRan
2 Lawter International
3 Lubrizol
4 Texasgulf
5 Nalco Chemical
6 Loctite
7 Great Lakes Chemical
8 International Flavors
9 Beker Industries
10 Petrolite

In all four measures of profitability, rankings were led by either smaller specialty chemical firms or by fertilizer makers. Specialty chemical companies perform well because of their high rates of return on their products due to the high value-added nature of those products. Fertilizer firms ranked high primarily because of large cyclical gains in profits in 1980 brought on by an excellent year both for U.S. and export markets.

Based on 1980 results reported by the 40 largest (in terms of sales) U.S. chemical companies, average profit margins (after-tax income as a percentage of sales) fell to 6.1% last year from 6.6% in 1979. This was higher in both years than the average for all manufacturing industries. According to figures published by the Federal Trade Commission, profit margins for the all-manufacturing category fell last year to an average of 4.9% from 5.7% in 1979.

The leader in profit margins among the 40 chemical companies in 1980 was Texasgulf, which rang up a return on sales of an outstanding 26.3%. This is even better than it did the year before, when it ranked second among the 40 companies with a profit margin of 17.3%. The highest profit margin in 1979 was posted by Freeport-McMoRan (formerly Freeport Minerals) with 20.8%; it placed second in 1980 although with a higher profit margin, 22.2%, than the year before.

Profit margins at U.S. chemical companies fell to 6.1% in 1980

Rank 1980	Rank 1979		Profit margin[a] 1980	Profit margin[a] 1979	Rank 1980	Rank 1979		Profit margin[a] 1980	Profit margin[a] 1979
1	2	Texasgulf	26.3%	17.3%	21	16	Diamond Shamrock	6.4%	7.6%
2	1	Freeport-McMoRan	22.2	20.8	22	22	Rohm & Haas	5.4	6.0
3	4	Great Lakes Chemical	14.9	15.2	23	30	Allied Corp.	5.2	4.1
4	3	Lawter International	14.7	16.4	23	10	Du Pont	5.2	8.5
5	5	International Flavors	14.1	15.0	25	23	Ethyl Corp.	5.1	5.8
6	6	Loctite	13.0	14.4	26	29	W. R. Grace	4.7	4.3
7	7	Lubrizol	12.1	12.5	27	26	American Cyanamid	4.6	5.3
8	8	Nalco Chemical	11.7	10.9	27	18	Hercules	4.6	7.4
9	24	Beker Industries	9.8	5.7	27	17	Thiokol	4.6	7.5
9	12	Petrolite	9.8	8.3	30	25	Monsanto	3.9	5.5
11	38	First Mississippi	8.6	2.6	31	28	Celanese	3.6	4.5
12	15	Air Products	8.1	7.9	32	32	Essex Chemical	3.6	3.9
12	13	International Minerals	8.1	8.2	33	27	Pennwalt	3.6	4.6
12	14	Mallinckrodt	8.1	8.1	34	33	Witco Chemical	3.5	3.8
15	10	Dow Chemical	7.6	8.5	35	35	Stepan Chemical	3.4	3.7
16	20	Liquid Air	7.2	6.6	36	36	Crompton & Knowles	3.2	3.0
16	9	Stauffer Chemical	7.2	8.9	37	37	B. F. Goodrich	2.0	2.8
18	21	Union Carbide	7.0	6.1	38	31	Olin	1.8	4.0
19	33	Williams Cos.	6.7	3.8	38	40	Reichhold Chemicals	1.8	1.4
20	19	PPG Industries	6.6	7.1	40	39	Akzona	0.5	2.5
							AVERAGE	6.1%	6.6%

a After-tax income as a percentage of sales

Return on investment dropped to 5.0%

Rank 1980	Rank 1979		Return on investment[a] 1980	Return on investment[a] 1979	Rank 1980	Rank 1979		Return on investment[a] 1980	Return on investment[a] 1979
1	2	Lawter International	16.5%	17.6%	21	27	Liquid Air	5.2%	4.6%
2	5	Freeport-McMoRan	15.6	14.4	21	30	Union Carbide	5.2	4.4
3	1	Loctite	15.5	18.0	21	17	Witco Chemical	5.2	6.0
4	4	Lubrizol	14.9	14.7	21	36	Williams Cos.	5.2	3.1
5	6	Nalco Chemical	14.5	13.8	25	21	Rohm & Haas	5.0	5.4
6	6	International Flavors	13.2	13.8	26	25	Air Products	4.9	4.9
6	11	Texasgulf	13.2	7.7	26	29	Crompton & Knowles	4.9	4.5
8	3	Great Lakes Chemical	12.7	15.1	28	20	Stauffer Chemical	4.7	5.8
9	9	Petrolite	11.0	8.5	29	17	Du Pont	4.3	6.0
10	22	Baker Industries	9.8	5.3	29	12	Hercules	4.3	6.9
11	8	Mallinckrodt	9.1	8.7	31	27	American Cyanamid	4.1	4.6
12	40	First Mississippi	8.2	2.0	32	25	Pennwalt	4.0	4.9
13	15	International Minerals	6.4	6.3	33	35	Allied Corp.	3.7	3.3
14	9	Thiokol	6.1	8.5	34	32	Stepan Chemical	3.6	3.6
15	16	Diamond Shamrock	5.9	6.1	35	38	Reichhold Chemicals	3.1	2.4
16	13	Ethyl Corp.	5.8	6.7	36	31	Monsanto	3.0	4.2
17	14	Dow Chemical	5.6	6.4	37	33	Celanese	2.8	3.5
17	24	W. R. Grace	5.6	5.2	38	37	B. F. Goodrich	2.2	3.0
19	22	Essex Chemical	5.3	5.3	39	33	Olin	1.5	3.5
19	17	PPG Industries	5.3	6.0	40	39	Akzona	0.4	2.2
							AVERAGE	5.0%	5.4%

a After-tax income as a percentage of current assets plus gross plant.

Below these two fertilizer and mineral companies, profit margins for the other 38 companies dropped fairly fast in 1980. The third-place company, Great Lakes Chemical, had a return on sales of 14.9% in 1980, considerably below Freeport.

The biggest jump in rank in 1980 was by First Mississippi, which leaped from 38th place in 1979 with a profit margin of 2.6% to 11th place in 1980 with a profit margin of 8.6%.

Of the 40 companies surveyed, just 14 posted increases in profit margins in 1980 from 1979, 25 had decreases, and one remained the same.

The average return on investment (net earnings as a percentage of current assets plus gross plant) fell to 5.0% in 1980 from 5.4% in 1979 for the 40 chemical companies. In this, the chemical industry posts a lower average than that for all manufacturing industries, which fell to 6.2% in 1980 from 7.3% in 1979.

All of the balance sheet percentages—return on investment, assets,

Return on assets decreased to 6.9%

Rank 1980	Rank 1979		Return on assets[a] 1980	Return on assets[a] 1979	Rank 1980	Rank 1979		Return on assets[a] 1980	Return on assets[a] 1979
1	1	Lawter International	18.7%	19.9%	21	18	Dow Chemical	6.9%	7.6%
2	4	Nalco Chemical	17.4	17.2	22	22	Air Products	6.6	6.9
3	3	Lubrizol	17.1	17.5	22	30	Liquid Air	6.6	5.8
4	7	Freeport-McMoRan	16.5	14.8	24	25	W. R. Grace	6.5	6.1
5	2	Great Lakes Chemical	16.0	18.7	24	18	Witco Chemical	6.5	7.6
6	6	International Flavors	15.2	15.9	26	35	Allied Corp.	6.4	4.2
7	5	Loctite	14.4	16.6	27	27	Essex Chemical	6.1	6.0
8	14	Texasgulf	14.3	8.3	28	11	Hercules	6.0	9.8
9	8	Petrolite	14.2	10.9	29	21	Stauffer Chemical	5.8	7.2
10	31	Baker Industries	10.1	5.4	29	37	Williams Cos.	5.8	3.5
10	12	Mallinckrodt	10.1	9.6	31	27	American Cyanamid	5.5	6.0
12	40	First Mississippi	9.0	2.3	32	32	Crompton & Knowles	5.2	5.0
13	17	International Minerals	7.9	7.9	32	23	Pennwalt	5.2	6.3
14	16	Rohm & Haas	7.6	8.0	34	29	Celanese	4.6	5.9
15	9	Du Pont	7.5	10.5	35	25	Monsanto	4.4	6.1
16	13	Ethyl Corp.	7.4	8.5	36	34	Stepan Chemical	3.9	4.7
16	14	PPG Industries	7.4	8.3	37	39	Reichhold Chemicals	3.8	2.8
18	20	Diamond Shamrock	7.2	7.4	38	35	B. F. Goodrich	2.8	4.0
18	23	Union Carbide	7.2	6.3	39	33	Olin	2.2	4.9
20	10	Thiokol	7.0	9.9	40	38	Akzona	0.6	3.1
							AVERAGE	6.9%	7.3%

a After-tax income as a percentage of total assets.

Return on stockholders' equity declined to 14.5%

Rank 1980	Rank 1979		Return on equity[a] 1980	Return on equity[a] 1979
1	1	Freeport-McMoRan	29.6%	26.7%
2	4	Lubrizol	24.6	24.2
3	20	Texasgulf	24.5	15.7
4	25	Beker Industries	24.1	14.2
5	4	Nalco Chemical	23.6	24.2
6	6	Lawter International	23.1	23.9
7	2	Loctite	22.6	25.2
8	16	Petrolite	22.2	16.7
9	3	Great Lakes Chemical	20.3	24.6
10	7	International Flavors	20.0	21.5
11	40	First Mississippi	18.6	4.1
12	11	Essex Chemical	18.3	18.1
13	8	Dow Chemical	18.1	20.1
14	15	Air Products	17.9	17.2
15	24	Allied Corp.	17.4	14.3
16	21	International Minerals	16.6	15.3
17	14	Diamond Shamrock	16.2	17.5
18	23	W. R. Grace	15.8	14.4
19	11	Witco Chemical	15.4	18.1
20	27	Union Carbide	14.6	13.8
21	36	Williams Cos.	14.4%	9.3%
22	25	Mallinckrodt	14.2	13.9
23	17	PPG Industries	13.9	16.4
24	9	Thiokol	13.6	19.6
25	18	Ethyl Corp.	13.5	16.0
26	22	Rohm & Haas	13.3	15.0
27	32	Liquid Air	13.2	11.7
28	18	Stauffer Chemical	13.0	16.0
29	13	Du Pont	12.6	17.7
30	10	Hercules	11.3	18.2
31	30	American Cyanamid	11.1	12.5
31	29	Celanese	11.1	13.6
33	34	Crompton & Knowles	11.0	10.8
33	28	Pennwalt	11.0	13.7
35	33	Stepan Chemical	10.7	11.3
36	39	Reichhold Chemicals	9.3	7.5
37	31	Monsanto	9.1	12.2
38	37	B. F. Goodrich	6.5	8.7
39	35	Olin	4.5	9.6
40	38	Akzona	1.5	7.9
		AVERAGE	14.5%	15.6%

a After-tax income as a percentage of year-end stockholders' equity.

and equity—in this survey are figured on companies' year-end data. This yields a more conservative figure than some companies' figures based on average balance sheet data for the year.

Among the chemical companies, Lawter International rose to number one in 1980 with return on investment of 16.5%. This is lower than its return on investment in 1979 of 17.6%, but still high enough to bring it up from second place in 1979 and beat return on investment at Freeport-McMoRan last year of 15.6%. Freeport's return improved from a year-earlier figure of 14.4%. This gain was enough to move it to second place in 1980 from fifth place in 1979. Loctite dropped to third place in 1980 from first the year before as return on investment fell to 15.5% from 18.0%.

The largest jump in rank once again was by First Mississippi, which rose to 12th place in 1980 from 40th in 1979. Then followed Beker Industries, which rose to 10th place last year from 22nd the year before. Hercules dropped most, to 29th in 1980 from 12th in 1979.

As in 1979, 15 companies' return on investment increased in 1980. Three of them had the same return on investment as they did in 1979, and 22 declined.

Average return on year-end assets for the 40 companies declined to 6.9% in 1980 from an average of 7.3% the year before. For all manufacturing, the percentage dropped to 6.7% in 1980 from 8.0% in 1979. Thus, while dropping, return on assets for the chemical companies moved ahead of that for all manufacturing after lagging in 1979.

As with return on investment, Lawter International led the pack in return on assets, just as it did in 1979. Even so, Lawter's return on assets declined in 1980 to 18.7% from 19.9% the year before. The decline was not enough, however, for Nalco to overtake Lawter, despite Nalco's rising return on assets. Second-place Nalco had return on assets of 17.4% in 1980, up from 17.2% (fourth place) in 1979. Lubrizol maintained its third-place rank on return on assets although falling to 17.1% in 1980 from 17.5% in 1979.

As in the other two measures of profitability—profit margin and return on investment—15 companies improved their return on assets in 1980 while 24 declined. One had the same percentage last year as it did the year before.

The greatest increase in rank was again for First Mississippi, which jumped to 12th place last year from 40th in 1979. First Mississippi was followed by Beker Industries, which climbed to 10th on the list in 1980 from 31st in 1979.

And once again, Hercules had the worst fall, dropping to 28th in 1980 from 11th the previous year.

Average return on equity for the 40 companies fell 1.1 percentage points in 1980 to 14.5% from 15.6% in 1979, which remained ahead of the average for all manufacturing industries despite the drop. Return on year-end equity for the all-manufacturing category last year was 13.5% compared to 15.8% in 1979.

Freeport-McMoRan led the list of chemical companies with a return on equity of 29.6% last year. Its return in 1979, also tops, was 26.7%. In fact, fertilizer companies generally scored high in 1980 in return on equity with three—Freeport, Texasgulf, and Beker—in the top five.

Texasgulf improved its rank to third last year from 20th the year before, with a return on equity of 24.5%, up from 15.7% in 1979. Beker moved up to fourth from 25th place in 1979, with return on equity of 24.1%, up from 14.2% in 1979.

Of the 40 chemical companies, 17 had better returns on equity in 1980 than in 1979 while 23 declined.

To come up with the top company in terms of profitability, C&EN added the rankings of the companies in each category and then ranked them from the lowest number to the highest. By doing this, Freeport-McMoRan edged out Lawter International for first place in overall profitability by virtue of its rank as number one in return on equity, number two in both profit margin and return on investment, and number four in return on assets. □

Water treatment chemicals use to grow strongly

Use of chemicals for treatment of water is slated to grow at an average annual rate of about 9.5% through 1990, according to a study by Business Communications Co., a market research firm in Stamford, Conn.

The BCC study says that the current market for these chemicals in municipal, private, and industrial water systems and in recycling of wastes amounts to about $680 million per year.

The growth for water treatment chemicals will be fed by a number of factors, including demand by the public for improved drinking water quality; increased urbanization, industrialization, and irrigation for agriculture; and increased water reuse and recycling, resulting particularly from water shortages.

The study indicates that demand for some specialty treatment chemicals will grow at a faster rate than bulk chemicals. However, lime and chlorine, the two largest-volume chemicals for water treatment, will remain the leaders for the next decade in total sales.

The use of chlorine in drinking water is still large at about $80 million in 1980, but the growth rate has slowed considerably to between 2.5 and 3.0% per year. This slowing has been caused largely by what the study calls "newly evaluated health hazards associated with the formation of chlorinated hydrocarbons."

Lime, however, likely will continue its steady growth until the time comes that other flocculating agents become less costly. Lime sales by 1985 are expected to reach $135 million.

The survey indicates that one of the most attractive and rapidly growing markets will be for activated carbon. This is forecast to grow at about 10% per year through 1990 to reach sales of about $100 million.

Polyelectrolytes will reach sales of about $120 million by 1990. BCC says that other chemicals showing great promise include ion exchange resins, hydrogen peroxide, oxygen, and ozone.

Bromine and iodine compounds may be developed for water disinfection. These will replace chlorine and chlor-amine type by-products that are suspected carcinogens, the study says.

BCC forecasts that the individual water market will grow faster, at an average annual rate of about 10.5% through this decade, than the municipal market, which is expected to grow at about 8% per year. Sales for these two markets will hit about $1.65 billion in 1990, compared with sales of about $664 million in 1980. □

Water treatment chemicals use will hit $1 billion in 1985

$ Millions	1971	1980	1985	1990	Annual growth 1980–90
Municipal	$ 90	$166	$ 250	$ 351	8.0%
Industrial	220	498	832	1300	10.5
Total	$310	$664	$1082	$1652	9.5%

Source: Business Communications Co.

Specialty plastics output dropped last year

Specialty plastics are an elite group in the overall U.S. plastics business, barely more than 10% the size of their distant commodity plastics cousins in production volume. Specialties draw a disproportionate share of companies' technical resources and cost customers two to three times as much on average as commodity plastics.

Unfortunately, the outstanding specifications of specialty plastics tie them to a lot of durable goods as end uses—autos and construction, most notably. That puts specialties very much in harm's way during business downturns, which affect durables strongly. In the past, specialty plastics have depended on high market penetration rates to save them from trouble in recessions. But nothing seemed to help very much in 1980.

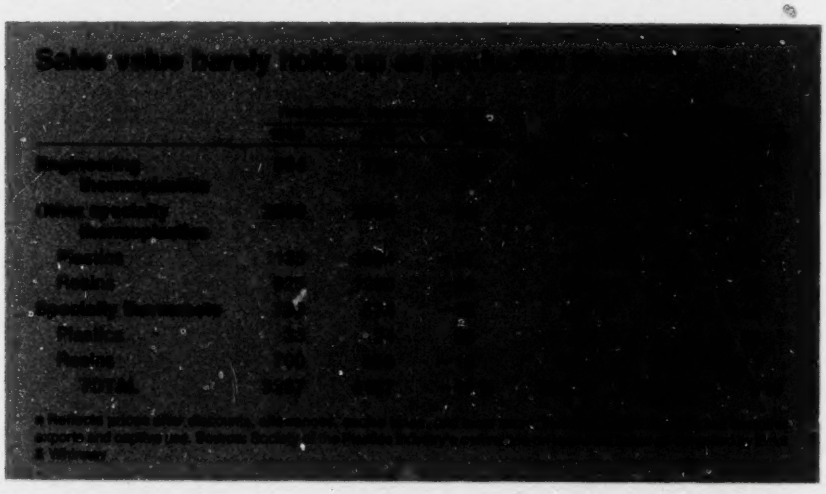
Specialty plastics got shellacked last year, with an overall production drop of 19%. By contrast, commodity plastics production fell about 10%. Dollar value of U.S. specialty plastics merchant sales was flat despite sizable price increases. That's the gist of the annual report on engineering and other specialty plastics put out by the Society of the Plastics Industry. The report is based on SPI's committee on resins statistics from company data compiled by accountants Ernst & Whinney.

Specifically, SPI finds total specialty plastics production in 1980 at 3.39 billion lb, down from 4.17 billion lb in 1979. Dollar value of U.S. merchant sales was $2.52 billion both years.

The market problem was mainly in the U.S., where sales and captive use fell 18%. However, even exports dropped last year, falling 5% from 1979. Exports are fairly important to specialty plastics, amounting to 12% of total sales.

The volume problem for specialty plastics spread throughout the three major subgroups SPI measures. Production fell 19% in engineering thermoplastics, 20% in other specialty thermoplastics, and 16% in specialty thermosets.

Dollar value of U.S. merchant sales of specialty plastics had a more uneven pattern, falling 8% in engineering thermoplastics and 16% in specialty thermosets but rising 7% in other specialty thermoplastics. □



Recent trends in chemical literature growth

Dale B. Baker, director
Chemical Abstracts Service

The growth of newly published chemical and chemical engineering literature has been slowing somewhat in recent years. The number of papers abstracted by *Chemical Abstracts* (*CA*) grew at an average annual rate of only 4.6% from 1976 through 1980, compared to 6.9% in the 1971–75 period, 8.4% in 1961–70, and 8.2% in 1951–60. Abstracts of patent documents declined at an average annual rate of 1.6% during the 1976–80 period as compared to an average annual growth of 10.2% during the 1971–75 period. The number of equivalent patent documents cited in the *CA Patent Concordance* grew at an average rate of 3.5% per year over the past five years as compared to 15.7% average annual growth during the 1971–75 period. (An equivalent patent is one covering an invention already patented in another country.)

In 1980, Chemical Abstracts Service (CAS) published a record 475,739 abstracts of papers and patents, up 8.9% from 1979. Including references for 72,937 patent equivalents, a total of 548,676 documents were cited in 1980, 6.4% more than in 1979. About 17,000 of the abstracts published in 1980 resulted from a 14-day shortening of processing time. Subtracting these from the total published would yield 458,739, an increase of about 5%, which is more in line with the recent five-year average annual growth.

For the five-year period 1976–80, *CA* cited a total of 2,499,709 documents, up from 1,915,610 documents during the previous five-year period, a 30% increase.

The total number of abstracts published in *CA* since 1907 now equals 8,544,400, and the number of documents cited totals 9,322,907. It is expected that the 9 millionth abstract will be published by November 1981, during *CA*'s 75th year of publication.

Growth by nations

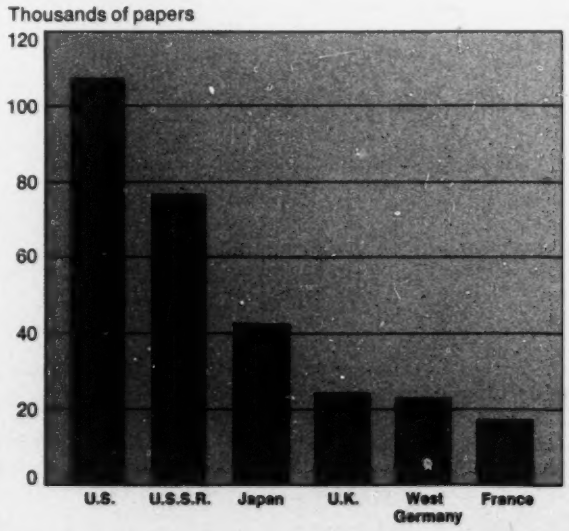
An analysis of the national origin of papers abstracted in *CA* provides a picture of the relative levels of chemical R&D activity in the different nations of the world. The data used in this analysis are based on the author's address included in most papers and thus reflect the nation in which the work was performed, whether or not the report was published in the same nation.

The U.S. continues to be the largest source of published reports of chemical and chemical engineering R&D, and this U.S. share has stabilized since 1972. The number of papers originating in the U.S. grew from 81,697 (25.8% of the worldwide total) in 1975 to 106,552 (26.2%) in 1980. The average annual U.S. share over the 1976–80 period was 26.3%.

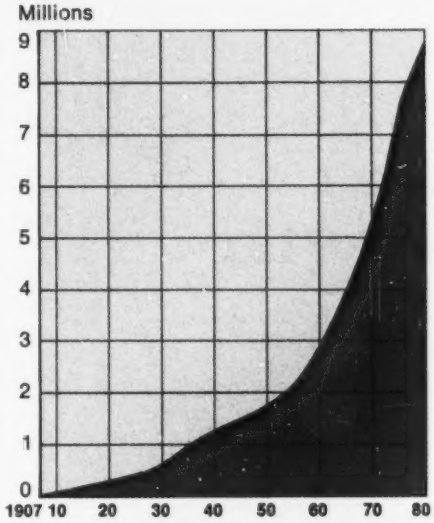
A major change was the decrease of the U.S.S.R. share of the total during this period from 24.6% in 1975 to 19.0% for both 1979 and 1980. In fact, the Soviet share hit a peak of 25.3% in 1974 and has declined every year since. It averaged 21.1% for the 1976–80 period.

To explain this decrease, the CAS staff has reviewed Soviet publishing practices and CAS acquisition of Soviet papers. Our examination of the *Referativnyi Zhurnal Khimiya* (the U.S.S.R. equivalent of *CA*) confirms that the Soviets likewise are publishing fewer abstracts of Soviet papers. The Soviet practice of depositing manuscripts in lieu of publishing may be reducing the rate of growth of their scientific literature. In 1979, the Central Committee of the Communist Party of the Soviet Union

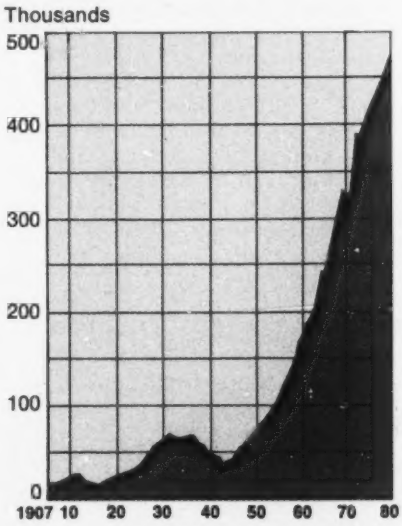
U.S. produced the most chemical papers in 1980



Abstracts published in *CA* will pass 9 million during 1981...



...with the number published annually nearing half a million



adopted a resolution "On Regulating the Size of Press Runs and Reducing the Number of Periodical Publications," the effect of which has been a 10% reduction in volume of publication in certain fields of science and technology.

The marked increase in Japanese journal literature in the past five years, to 10.4% of the total in 1980 from 7.3% in 1975, is typical of Japan's recent thrusts in all fields of science and technology. The share of the world's journal literature originating in Japan averaged 9.1% over the 1976–80 period, compared to 7.5% during the 1971–75 period.

The chemical journal literature from the U.K. has declined slowly as a percentage of the world total during the past five years. The U.K. produced 5.9% of the total in 1980 compared to 6.4% in 1975. Meanwhile, India's share has grown from 2.7% of the total in 1975 to 3.4% in 1980. In all, 146 different nations contributed in 1980 to the new literature of chemistry and chemical engineering. Only 12 of these accounted for 85% of the total.

The Comecon nations of Eastern Europe, as a group, accounted for 26.2% of the total papers in 1980, compared to 32.0% in 1975. Whereas the share of papers originating in Romania increased to 0.6% and that of Poland and Yugoslavia held even at 2.1% and 0.5%, respectively, the contributions of Bulgaria, Czechoslovakia, East Germany, and Hungary all declined slightly.

Publication continues to increase in the People's Republic of China. That country produced 0.7% of total papers abstracted in 1980, up from less than 0.1% in 1975. CAS now is receiving 94 journals from China, compared to 28 in 1975 and none in 1973.

Languages in publications

The increase in the use of English in the primary chemical literature continues to be amazing. In the 20 years that detailed statistics have been collected at CAS on the languages in which abstracted papers are published, the percentage of papers published in English has increased from 43% in 1961 to 64.7% in 1980. There was a 5.0% increase in the past five years alone. Part of this increase since 1975 is due to the decline of the share of the literature originating in such non-English-speaking nations as the U.S.S.R. and the Comecon countries.

The increase in the use of Japanese in the chemical literature from 3.0% in 1975 to 5.2% in 1980 is not too surprising in light of the growing share of the world's chemical literature coming from Japan. However, it does appear that a trend to publication in English by Japanese scientists is being reversed. Some 60% of the papers published in 1975 reporting on work performed in Japan were published in languages other than Japanese. This is now down to 50%. Japanese has replaced German as the third most widely used language (after English and Russian) in chemical publications.

The use of German (now 4.0% of the total) and French (2.0%) has declined dramatically in the past 20 years. Polish (1.1%) and Italian (0.8%) have dropped to sixth and seventh positions, respectively. In fact, the use of Chinese (in 3118 papers in 1980) has nearly caught up with the use of Italian (in 3126 papers). Papers also appeared in 43 other languages in the published literature covered in *CA* in 1980.

Literature sources by state

Creating computer-readable files of information on all the papers abstracted has made it readily possible to determine the sources of the U.S. journal literature according to the state in which the reported work was performed. The state indicated in the author's address is the basis for establishing where the work was done.

In 1980, 10 states accounted for 59.5% of U.S. papers, and 19 states and the District of Columbia accounted for 80.4%. In 1975, the top 10 states had 62% and the top 20 82%.

California ranks first in producing chemical papers, followed by New York and Massachusetts. Four of the top 10 states have changed their relative rank as sources of chemical papers since 1975. Illinois, fifth in 1975, now ranks fourth, while Pennsylvania has dropped to fifth.

Highlights from previous articles

Statistics available as a by-product of the computerized production of *Chemical Abstracts* show trends over time regarding national sources and languages of technical papers, patent production by country, and the volume of publications in various subdisciplines of chemistry. These statistics have formed the basis of a series of articles that I have enjoyed writing for C&EN every five years beginning with 1961.

Since the series now spans the quarter of a century during which 70% of the total chemical literature abstracted and indexed in *CA*'s 75-year history has appeared, the reader may be interested in a brief summary of a few highlights from previous articles. The difficulty, of course, is that some of the highlights include my assessment (at the time) of what the future would hold for the world as reflected by the chemical literature it produces. Alas, my crystal ball has had some downtime along the way. Such is the risk in prophesying.

Article highlights	Comments
July 17, 1961	
• China must be reckoned with as a major research nation in the next decade or so.	• Because of internal political factors, China resumed producing chemical literature in 1973, after a six-year hiatus.
• If research activities in the U.S. and U.S.S.R. continue at present rates, the volume of Soviet chemical literature will equal that of the U.S. in 1965.	• The U.S.S.R.'s share of the literature has never surpassed the U.S. share; the two were closest in 1971–75, with the U.S. at 26.8% and the U.S.S.R. at 24.5%.
• A heeling over of the growth curve in research activity (as reflected in growth of chemical literature) can be expected in late 1960's.	• Overall decline in growth of chemical literature only now is being seen in statistics for the 1976–80 period.
• Approximately 290,000 papers reporting new research results are anticipated by 1970.	• CAS was abstracting and indexing 300,000 papers, patents, and reports in 1970.
June 6, 1966	
• If the present rate continues, CAS will have published its 7 millionth abstract by 1977.	• This milestone was indeed reached in 1977.
July 12, 1971	
• CAS will be publishing 600,000 abstracts per year, for a cumulative store of more than 7 million abstracts, by 1980.	• CAS published more than 475,000 abstracts in 1980 (see comment above concerning 7 million abstracts).
May 10, 1976	
• U.S. share of articles abstracted and indexed in *CA* continues to decrease while the share held by the U.S.S.R. increases.	• Recent statistics suggest that this trend is changing.
• Growth of the chemical and chemical engineering literature seems unlikely to slacken much in the next decade.	• A slowing of the growth rate is beginning to appear.

Texas has moved from eighth to seventh rank, and New Jersey has dropped to eighth. Two new states appear among the second 10 for 1980: New Mexico now ranks 15th and Virginia is 19th. Florida and Colorado, which ranked 19th and 20th in 1975, no longer are among the top 20 states. Tennessee, which ranked 15th in 1975, moved up to 11th position. Washington moved from 17th to 14th and North Carolina from 14th to 13th. Indiana, which ranked 13th in 1975, dropped to 18th, and Wisconsin, 12th in 1975, is now 16th.

After I published similar data for 1975, letters to C&EN suggested that I put productivity by states on a per capita basis, which I have done, with data on papers per ACS member residing in the state. The per capita and per ACS member data for the District of Columbia skew the relationships considerably; data for Maryland and, to a lesser extent, Virginia are affected by these states' proximity to the District of Columbia. The wide range in papers per capita (0.35 to 1.72, eliminating D.C.) or per ACS member (0.51 to 3.60) raises some interesting questions. If you have suggestions on the reason for these wide ranges among the states or wish data for other states, please contact the author.

Growth by subdisciplines

Each abstract published in *CA* is assigned to one of 80 specific sections according to the principal subject content of the document abstracted. The relative growth of the sections and groupings of sections provides at least a gross indication of the change in emphasis in chemical R&D over a given period. (See C&EN, July 28, 1980, page 49 for further detail on growth of some sections and the groupings.)

The most rapid growth in the past five years has been in the applied chemistry and chemical engineering sections, which have grown at an average annual rate of 9.4%, up from 7.1% in the 1971–75 period. This increase in application and technological work is seen in most nations, not just in the U.S.

The biochemistry sections were second in growth in the 1976–80 period, growing to an average annual rate of 5.6%, down from their 10.1% annual growth in the 1971–75 period. The number of abstracts published in the organic chemistry sections decreased at an average annual rate of 0.8% from 1976 through 1980. The organic sections had grown at an average annual rate of 3.6% from 1971 through 1975 and 6.4% during the 1966–70 period. The macromolecular sections, which had been the most rapidly growing sections—11.6% per year—in the 1971–75 period, showed an average annual decrease of 3.2% between 1976 and 1980. Particularly large declines in publication on macromolecular topics were seen in 1976, 1977, and 1979.

At a more detailed level, *CA*'s fastest growing individual section over the past five years was section 52, which covers electrochemical, radiational, and thermal energy technology. This section was redesigned in 1974 to pull together all papers dealing with chemical and chemical engineering aspects of energy sources, conversion, and utilization other than fossil and nuclear fuels,

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U.S., Japanese share of journal literature is increasing, Soviet share is decreasing

	1956	1960	1965	1970	1975	1980
U.S.	28.4%	27.1%	28.5%	27.4%	25.8%	26.2%
U.S.S.R.	13.5	19.1	20.7	23.6	24.6	19.0
Japan	10.4	7.8	7.3	7.2	7.3	10.4
Germany (East and West)	8.4	7.8	8.5	6.5	6.8	7.0[a]
U.K.	7.5	7.7	6.7	6.2	6.4	5.9
France	6.0	5.0	4.5	4.1	4.1	4.2
India	na	2.2	2.2	2.7	2.7	3.4
Canada	na	1.9	2.0	2.4	2.7	2.6
Italy	4.1	3.2	2.7	2.7	2.1	2.4
Poland	na	na	2.9	1.8	2.1	2.1
Czechoslovakia	1.6	2.0	1.6	2.0	1.6	1.4
All others	20.1	16.2	12.4	13.4	13.8	15.4

Note: Figures are percentages of *CA* journal article abstracts by country in which reported work was performed. a West Germany, 5.8%; East Germany, 1.2%. na = not available, included in "all others."

propellants, and explosives. The number of abstracts published in the section increased 201% between 1975 and 1980. Other individual sections showing very rapid growth over the past five years are: section 61, water (134%); section 71, nuclear technology (102.4%); section 59, air pollution and industrial hygiene (89.5%); section 47, apparatus and plant equipment (85.2%); section 48, unit operations and process (83.3%); and section 60, sewage and wastes (68.4%).

Journals abstracted

In 1980, CAS actively monitored 12,728 "live" primary scientific and technical journals, 9401 of which published at least one article selected for abstracting during the year. In 1975, the number of journals monitored was 11,953, from 7536 of which at least one paper was abstracted. Thus, although the number of journals being monitored increased little more than 1% per year, the number producing one or more papers of chemical interest increased some 5% per year. Journal articles accounted for 73% of *CA* abstracts in 1980, compared to 69.2% in 1975, indicating an apparent reversal of the trend to other forms of publication for the dissemination of primary literature.

The average number of articles abstracted per journal increased slightly, from 36 in 1975 to 37.1 in 1980. In 1980, 485 journals produced 50% of the journal articles abstracted in *CA*, 1674 produced 75%, and 4145 produced 90%. The 5256 remaining rare journals, which produced 10% of the articles abstracted, are the most difficult to acquire in a regular fashion and are often the most sought after.

Papers selected for abstracting from conference proceedings volumes increased from 32,370 in 1975 to 35,213 in 1980, but the percentage of the total abstracts resulting from conference proceedings volumes decreased from 8.26% in 1975 to 7.42% in 1980. Abstracts of dissertations decreased from 1.61% of total abstracts in 1975 to 1.43% in 1980. The number of technical reports abstracted increased dramatically, from 7245 in 1975 to 16,762 in 1980.

In the Soviet Union, certain edited manuscripts of chemical interest are deposited in a central facility at the All-Union Institute of Scientific & Technical Information (VINITI) in Moscow and announced only through brief abstracts in a *Katalog Deponirovannykh Rukopisei*. The number of manuscripts of chemical interest so announced hit a peak of 2480 in 1979 and declined in 1980 to only 933. In 1975 the number was about 930. Stukalin (*1*) has stated that "the implementation of this method (disposition) of conveying information, despite its obvious advantages, has been encountering great difficulties." Soviet scientists and specialists consider deposited manuscripts as "second class" and do not recognize the right of a deposited manuscript to be included in the list of publications on dissertation topics, in spite of the resolution of the Central Committee that would require wide-scale deposition of manuscripts by the members of the U.S.S.R. Academy of Science—as high as 10 to 15% of the volume of the journal papers.

Patent literature

In its patent coverage, CAS distinguishes between "basic" patent documents—the first patent document to be published on a particular invention or, at least, the first to be received at CAS—and "equivalent" patent documents—those issued subsequently by another nation on an invention covered by a basic patent document. CAS abstracts only the basic patent documents and, through 1980, listed the equivalent documents in a patent concordance, which referred the searcher to the abstract of the basic document. (A new Patent Index that indexes both basic and equivalent patent documents and lists complete "families" of patents on the same inventions was added to *CA* in 1981.)

Patent documents now make up 24.6% of the total bibliographic items cited by *CA*, compared to 29% in 1975 and 25% in 1970. About 54% of the 134,935 patent documents cited in 1980 were equivalents. The 61,998 abstracts of patent documents published in 1980 are 9.4% fewer than the peak of 68,471 in 1975.

Japan, which started to publish unexamined patent applications in 1972, issued 40.4% of the 1975 patent documents abstracted in *CA*. This increased to 43.4% in 1980. West Germany, which also publishes unexamined patent applications, continues to issue the second largest number of basic chemical patent documents, 12.1% of the total in 1980, down from 20.3% in 1975. The U.S., which still publishes only examined patents, ranks third with 11.3% of the total. The U.S.S.R. has not increased the number of chemical patents it issues, but its relative percentage of total patents abstracted has increased from 8.8% in 1975 to 9.7% in 1980. The U.K. has moved from

Use of English in journal literature continues to grow

Language of papers abstracted	% of papers abstracted				
	1961	1965	1970	1975	1980
English	43.3%	52.0%	56.4%	59.7%	64.7%
Russian	18.4	20.0	22.6	23.3	17.8
Japanese	6.3	4.0	3.4	3.0	5.2
German	12.3	9.8	6.6	4.8	4.0
French	5.2	5.1	4.0	3.0	2.0
Polish	1.9	1.9	1.1	1.2	1.1
Italian	2.4	1.9	1.4	0.7	0.8
All others	10.2	5.3	4.5	4.3	4.4

3.3% of the total in 1975 to 4.9% of the total. France continues to drop in both actual number of chemical patents issued as well as in percentage of the total, from 4.0% in 1975 to 1.7% in 1980. Italy has issued no basic chemical patents since 1978.

Japan also produced the largest number and percentage of equivalent patent documents cited in 1980, 22.4%, up from 19.8% of the total in 1975. The U.K. issued 13.7% of the total patent equivalents cited in 1980, the U.S. 12.4%, and Canada 10.7%. There has been a dramatic decline in filing of equivalent patents in France (down from 14% of the total in 1975 to 7.6% in 1980) and the Netherlands (down from 9.8% in 1975 to 3.4% in 1980).

It is interesting to note that no U.S.S.R. patent equivalent showed up until 1978, when 710 equivalents were covered in *CA*. This increased in 1979 to 1388, but fell to 735 in 1980. Obviously, Soviet inventors now have started to file patents in other countries and, conversely, some inventions patented in the 25 other nations whose patents CAS covers also have been patented in the U.S.S.R.

Those interested in further detail on the patent coverage in *CA* should read "Gleaning Patents with *Chemical Abstracts*" by R. J. Rowlett Jr., in *CHEMTECH*, Vol. 9, June 1979, page 348.

80% of U.S. chemical journal literature is produced in 19 states and D.C.

Rank	State	Abstracted papers originating in state	% of total U.S. papers abstracted	Papers per 1000 residents	Papers per ACS member
1	California	14,722	13.8%	0.62	1.55
2	New York	10,870	10.2	0.62	1.23
3	Massachusetts	5,873	5.5	1.02	1.55
4	Illinois	5,418	5.1	0.47	0.94
5	Pennsylvania	5,264	4.9	0.44	0.77
6	Maryland	5,037	4.7	1.19	1.72
7	Texas	4,825	4.5	0.34	0.94
8	New Jersey	4,345	4.1	0.59	0.51
9	Ohio	3,955	3.7	0.37	0.67
10	Michigan	3,186	3.0	0.34	0.82
11	Tennessee	2,694	2.5	0.57	1.62
12	District of Columbia	2,666	2.5	4.18	3.08
13	North Carolina	2,565	2.4	0.44	1.23
14	Washington	2,266	2.1	0.55	1.77
15	New Mexico	2,131	2.0	1.72	3.60
16	Wisconsin	2,129	2.0	0.45	1.24
17	Connecticut	2,082	2.0	0.67	0.86
18	Indiana	1,990	1.9	0.36	0.88
19	Virginia	1,983	1.9	0.37	0.88
20	Missouri	1,743	1.6	0.35	0.84

Note: Data for 1980.

Chemical Registry System

All unique chemical substances indexed for *CA* since January 1965 have been recorded in the files of the CAS Chemical Registry System. This computer-based system uniquely and unambiguously identifies each substance on the basis of its two-dimensional structure and stereochemical characteristics. The system also links to the structure record the various names by which the substance has been identified in the literature and its systematic *CA* index name.

At the end of 1980 the number of unique registered substances was more than 5.1 million, up from 3.4 million in 1975. Along with the 5.1 million unique substances there are now almost 8 million associated names constituting the nomenclature file.

A total of 353,881 new substances were added to the registry system during 1980, compared to 372,492 in 1975 and 288,085 in 1970. The number of new registrations has leveled off at a fairly constant rate of about 7000 per week. The 5 millionth substance was entered Aug. 12, 1980.

In 1980, CAS completed a feasibility study on how registration of chemical substances from pre-1965 indexes of *CA* could best be accomplished. It was estimated that there were about 2 million unique substances indexed between 1907 and 1965 that are not presently in the registry system. These, added to the 5.1 million already registered, indicate a total of about 7 million known chemical substances. It would be especially useful to industry and the patent offices if these additional substances were identified for fast, easy retrieval from the data base.

Indexing density

The average number of index entries published for each document indexed in *CA* has continued to increase gradually over the past five years, indicating that the nature and information content of the chemical and chemical engineering literature is continuing to change. General subject index entries have increased from 2.3 per abstract in 1975 to almost 2.5 (a total of about 1.2 million entries) in 1980. Chemical substance index entries have leveled off at about 4.1 entries per abstract, for a total of about 1.93 million entries in 1980. Formula index entries are at 1.8 per abstract, about 861,000 entries for 1980. Patent and patent equivalent entries totaled about 580,000 in 1980. The average number of authors per paper has increased from 2.46 in 1975 to about 2.7 (about 1.3 million total author index entries) in 1980.

Quality of chemical information

We at CAS often are asked to comment on the quality of the original chemical information being processed and disseminated. It has been suggested that CAS limit coverage to only "important" or "useful" information. It is our position that no effective measuring devices or evaluative tools have been developed to date to judge what is "most important" or "useful" chemical information. In addition, CAS's professional staff is just a small part of the overall profession of chemistry, a part trained in analyzing, not evaluating, the literature.

If 100 chemists were asked what is most important or of highest quality in the chemical literature (the responses to be used as a possible yardstick), there would be little or no correlation in their responses. Author citations in references have been used as a yardstick, but there are wide variations in the use of citations based upon the nations in which the work is performed. Another yardstick is the peer review system, which has worked effectively for many years.

Admittedly, any filter such as author citations or peer review will allow a considerable amount of material to be circulated that may not be of discernible value now or in the near future. Although it may be possible to introduce additional filters in the years ahead to reduce the number

of such references, the responsibility for assessing the quality and usefulness of the information still rests with authors, publishers, and users.

The next decade

My prognoses for the future in past articles in this series have not always materialized. Undoubtedly, my view again will be sharpened by hindsight as I look back on the decade of the 1980's. For now, I must view the decade from the present.

The deceleration in growth of the chemical literature over the past five years makes it difficult to predict growth patterns even for the next five years. A simple extrapolation of the growth curve would indicate a continued heeling over, with annual growth gradually slowing. Publication in applied chemistry and chemical engineering and biochemistry is likely to continue to grow at a rate greater than the growth rate for chemical literature as a whole. Publication on physical and analytical chemistry could continue to grow at about the median rate. However, the rate of decline in publication on organic chemistry and macromolecular chemistry is likely to be greater than that recently experienced and thus offset any increases in applied chemistry and biochemistry. Certainly, interdisciplinary and mission-oriented R&D will continue to grow worldwide as every nation strives to solve its problems of quality of life as well as to improve its socioeconomic situation by producing more competitive products and services for world markets.

I also perceive several trends that may change the reporting of chemical information in the coming decade.

In discussing the U.S.S.R.'s automated information system for scientific and technical information, Soviet officials have stated (2): "The efficiency of the whole information system . . . could be considerably improved by reducing the expenditure on the processing of primary documents. . . . The optimum solution for controlling primary information flow is still to be found." As the Soviet Union implements this system, the concepts of strong control and reduction of expenditures could indeed adversely affect free flow beyond national borders, a situation already indicated by the decline in the source literature from the U.S.S.R. in the past several years. Let's hope that these restrictions do not further develop in the future and go against the long-standing principles of international exchange of scientific and technological information. Regulation, whatever the source, of the international flow of scientific and technical information is a storm cloud gathering on the horizon, ominous to the well-being of worldwide science and technology.

CAS director Dale Baker

Today, all major science abstracting and indexing services in the noncommunist world are nearly fully computerized in the production and distribution of their publications and services and, thus, have data bases that can be searched on-line or off-line. Some of the world's thousands of primary journals also now are composed or distributed electronically. All American Chemical Society journals now are composed by computer (except for tables, charts, and reaction schemes) at CAS. The ACS Books & Journals Division currently is conducting experiments to determine the best strategy for on-line searching of the full text of papers and the cost effectiveness of such searching. Other major publishers are carrying out similar experiments.

The results of these experiments could have profound effects on abstracting and indexing. A major thrust is possible in the next five years to provide on-line searching of journal text—either by the publishers themselves or through delivery of text to search centers electronically in the manner that the abstracting and indexing services have been delivering information for the past 10 to 15 years. These efforts will start gradually, but momentum could grow rapidly as techniques are improved and costs of delivery decrease. The technology is available now, but the economics are largely unknown. Although electronic delivery of primary papers is likely to supplement rather than replace printed forms of delivery over the next 10 years, ACS has much at stake in these developments, which will be most interesting and challenging in the decade ahead. □

Biochemistry remains largest subdiscipline, but applied chemistry is growing most rapidly

Section grouping	Papers and patents abstracted in 1980	% of total *CA* abstracts	Average annual growth 1976–80	1971–75	1966–70
Biochemistry	169,444	35.6%	9.4%	7.1%	7.0%
Physical and analytical chemistry	126,851	26.7	5.6	10.1	6.8
Applied chemistry and chemical engineering	101,824	21.4	4.4	6.0	8.3
Organic chemistry	39,081	8.2	−0.8	3.6	6.4
Macromolecular chemistry	38,539	8.1	−3.2	11.6	9.5

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2. Losev, K. S., Turtanov, N. V., "Oriented Scientific Programs and the Development of Information Research in the U.S.S.R.," *Information Processing and Management*, **16**, 223 (1980).

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- ***NIH criticizes UCLA medical researcher*** *for conducting unapproved experiments involving recombinant DNA techniques.* ***Page 6***
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- ***Lab chemicals market to flourish*** *in climate of strong new R&D growth through 1985 in all major lines after product-line shakeouts in the late 1970's.* ***Page 10***

International

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C&EN's annual survey of the chemical industry, *both U.S. and foreign, finds low demand, high costs, and sagging productivity kept profits down.* ***Page 30***

Preliminary Program

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Lab chemicals market: small but growing

After product-line shakeouts in the late 1970's, specialty producers of lab chemicals see growth through 1985 in major lines, spurred by R&D

Stephen C. Stinson
C&EN, New York

The U.S. chemical industry offers no better examples of specialization than the highly complex laboratory chemicals market. Dominated by six major producers, this field has emerged shaken up but distinctly improved from the late 1970's. For the next five years, a climate of strong new growth in research and development in general has laboratory chemical producers and observers looking for modest to moderate growth in all five major product lines.

In 1981, U.S. chemists will buy $284 million worth of a myriad of laboratory chemicals and solvents for testing, teaching, research, and development, C&EN estimates after a survey of producers. By 1985, this figure could grow to $350 million in constant dollars.

Compared to the rest of the chemical industry, this is a small market. Still, dozens of companies will compete vigorously for every dollar, stepping up their efforts on new product development, production efficiency, distribution speeds, and re-examinations of product lines.

Looked at one way, laboratory chemical sales of all these companies will be less than half the 1980 chemical sales of Nalco Chemical Co., which is the smallest company on C&EN's list of the Top 50 chemical producers (C&EN, May 4, page 40). Looked at another way, these sales are less than half the value of all the adipic acid sold in 1980, which was at the bottom of C&EN's list of the Top 50 chemical products (C&EN, May 4, page 36).

Indeed, a few parent companies will look at their involvement in the laboratory chemicals business in the next few years, wondering if they should continue in it. At the same time, other companies are studying the business and a few of the supplier firms in it, looking to enter the business by acquisition.

The main classes of laboratory chemicals are inorganics (which are usually taken to include common solvents), organics, biochemicals, radiochemicals, and gases.

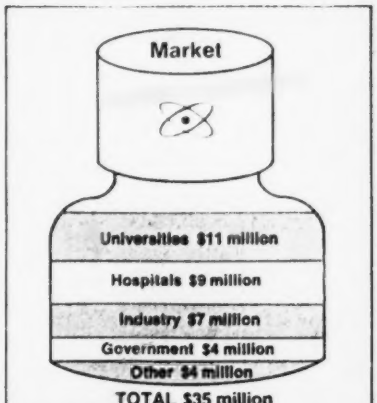
Inorganics are the largest class, with sales estimated by suppliers at $125 million in 1981, or 44% of the total. An overall study of this market by consultants Charles H. Kline & Co., Fairfield, N.J., predicts that this group will have real growth of 2.2% through 1985. This suggests that in 1985, inorganics and solvents will have sales of more than $135 million in constant dollars.

Second in dollar volume are organics, excluding solvents, whose 1981 market share of 18% will come to $50 million, industry sources forecast. Kline sees this group growing at 4.6% annually, which could bring constant-dollar 1985 sales to $60 million.

Next come biochemicals, which, at $40 million this year, will comprise 14% of the whole industry, sources expect. Kline says that increased research in the life sciences will fuel biochemicals to the fastest growth of any category—7.8% yearly, bringing 1985 sales to almost $55 million.

The same increased activity in biomedical research and testing may produce a similarly high growth rate of 7.4% per year for radiochemicals, according to Kline. The $35 million of 1981 radiochemicals laboratory sales

Radiochemicals follow life sciences research to prosperity



Source: Industry estimates

Radiochemicals as well as biochemicals will benefit from increased government funding of and industrial attention to life sciences research. Real-dollar growth in this market segment has been small in recent years, because increases in government funding of academic research have barely kept pace with inflation, and because of severe price competition. Nevertheless, chemical industry consultant firm Charles H. Kline & Co. predicts a growth rate of 7.4% annually through 1985.

Radiochemicals are very pure specialty compounds synthesized to incorporate such radioactive isotopes as tritium, carbon-14, phosphorus-32, and sulfur-35. They do not include deuterated compounds or those enriched in carbon-13. Likewise, kits for such clinical diagnostic tests as radioimmunoassay and radiopharmaceuticals for diagnosis and disease treatment are excluded.

Of the $35 million worth of radiochemicals chemists will buy in 1981, New England Nuclear, Boston, will sell about $17 million worth and Amersham Corp., Arlington Heights, Ill., will take orders for $5 million to $7 million worth. The rest will be divided among such producers of broad product lines as ICN Pharmaceuticals, Irvine, Calif., and Schwarz/Mann, Orangeburg, N.Y., and dozens of producers limited to a few products.

Amersham distributes products imported from Amersham International, formerly Radiochemical Centre, Amersham, England. Du Pont acquired New England Nuclear in April.

Radiochemicals is a hard business to enter, because of need to get government licenses, regulations on disposal of synthesis wastes, inventory costs on a broad product line, and difficulties in synthesis, packaging, and distribution. These reasons also preclude sales through distributors. Burial of a drum of synthesis wastes currently costs producers about $300.

estimated by suppliers could thus become almost $50 million in 1985. Figures for biochemicals and radiochemicals exclude those that are incorporated into clinical diagnostic kits, which sell for far more than the value of the chemicals contained.

The smallest dollar share will go to gases, amounting to $32 million this year by producer estimates. Nevertheless, Kline forecasts a steady 5.8% annual growth for this class, which could bring 1985 sales to $40 million.

Among laboratories that buy chemicals are industrial, which use them for quality control and effluent testing as well as research and development. Kline predicts that industrial laboratories will buy about $125 million worth of chemicals in 1981, 44% of the total, and almost half of these will be inorganics and solvents. Kline says that industrial laboratory buying will increase at 4.9% per year to $150 million in 1985.

On the industrial scene, chemicals consumption has been relatively unaffected by changes in research directions or the economy. Past experience leads industry observers to formulate a kind of Ricardo's Iron Law of Budgets, in which there is a roughly constant amount of money for research, whether used to develop new products or defend or improve old ones. This may change in the 1980's as companies reinvigorate new product research and make sizable increases in overall research budgets.

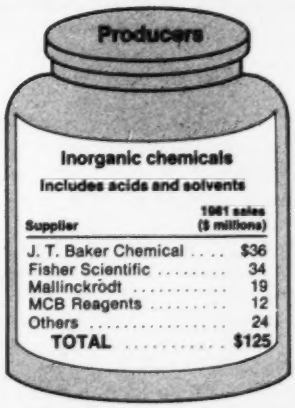
Though many firms are expanding into the life sciences, suppliers predict that chemical purchases there probably will be small and come at the expense of opportunities passed up elsewhere.

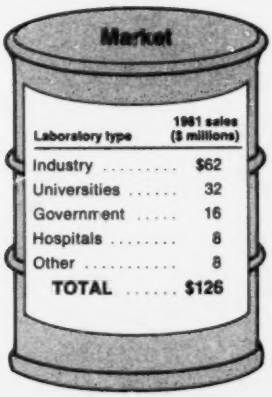
There is expectation that the regulatory climate will be less stringent in the 1980's than in the 1970's, but companies still must do testing to comply with laws and regulations. Although production may fall off during economic slumps, there is still a certain zero-point level of quality control testing that must be done.

Universities come second as laboratory chemical buyers. Their $73 million of orders this year will be 26% of the market, Kline says. Laboratory chemicals are used for instruction as well as research. Kline says that universities will increase purchases at a 5.4% annual rate, which could bring the figure to $90 million in 1985.

The Scientific Apparatus Manu-

Inorganics show slow growth of maturity





Source: Industry estimates

Inorganic laboratory chemicals are the largest component in the laboratory chemicals market but seem slated for the slowest growth in the next few years. Industry sources indicate that the total 1981 U.S. market for this group is $125 million, but it could be more than that. Consultant firm Charles H. Kline & Co. predicts an annual growth rate of only 2.2% through 1985.

Though suppliers think of this category as "inorganic chemicals," they also include common solvents under this heading. "General chemicals" might thus be a more apt name. Also included are prestandardized concentrates and solids for dilution as well as many indicator dyes.

At least 90% of inorganics are sold through distributors by such companies as J. T. Baker, Fisher Scientific, Mallinckrodt, and MCB Reagents. Many common reagent-grade salts and acids are available from such direct selling firms as Aldrich Chemical and Alfa Products. These two companies started by selling esoteric compounds and depend on small, customized sales for their strength, but they have added common inorganics to broaden their product lines. In a sense, Fisher also counts as a direct seller, because it distributes its own chemicals through an in-house distribution arm as well as those of Kodak Laboratory Chemicals. Kodak beefed up its own line of inorganic chemicals to 250 by adding 150 items this spring.

Catalog prices for inorganics can vary widely, and buyers cannot always depend on companies that sell direct to have lower tabs. In addition, managers of storerooms who place large, periodic orders for chemicals and apparatus usually can count on discounts of 20% or more from list prices. Those firms who sell through distributors offer a standard 40% discount from catalog prices to their distributors, who can use this margin to compete with others for such large orders. Chemists placing small orders for inorganics should shop among many catalogs.

Exports and imports of inorganics for laboratory use each may amount to $10 million per year. Most of these are uncommon compounds or those of a particular high purity. For example, most lithium aluminum hydride used in the U.S. is imported from West Germany, whereas the U.S. is almost the sole world source of Coleman's reagent, disodium tetracarbonylferrate. U.S. and user chemists buy almost all such imported compounds from American-based reseller companies, though.

Reliable data on amounts of laboratory inorganics going to different types of laboratories or on market share of producer firms are unavailable. Industry sources indicate that J. T. Baker and Fisher Scientific each have between 25 and 30% of this market, but it's not certain which has the larger share. Similarly, industrial laboratories are thought to take about half of the dollar volume in this category, while one quarter goes to universities.

As with organic chemicals, none of the producer firms can make all of the 1000 or so inorganics and solvents that they sell, direct or through distributors. Producing just 35 to 40% of their line, they make up the rest by purifying crude grades of compounds from bulk suppliers and by buying compounds from each other for repackaging under their own labels.

facturers Association in Washington, D.C., notes that there will be a modest increase in university enrollment in the 1980's, and that more and more students are turning to such laboratory-oriented majors as medical technology and medicine at the expense of the social sciences. On the other hand, suppliers are uncertain whether universities can replace money for research from industrial sources in cases where it declines from government agencies. Thus the growth rate in university laboratory chemicals buying may be somewhat less than Kline predicts.

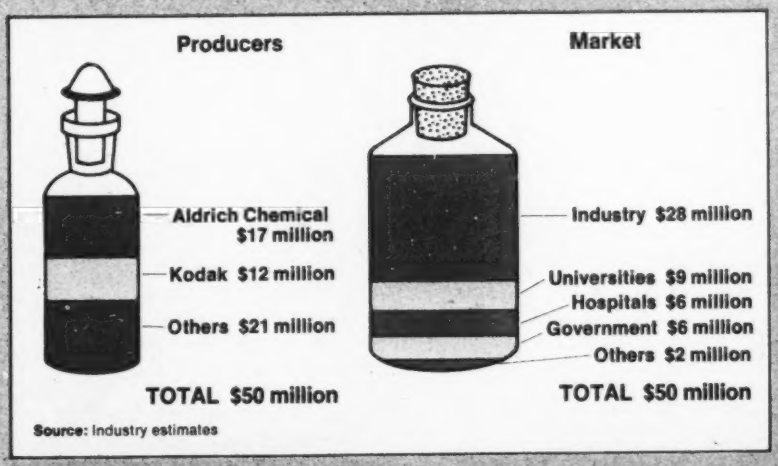
Government laboratories will buy $39 million worth of chemicals in 1981, or 14% of the total, according to Kline. Kline sees this market segment increasing at 5.6% per year, which may mean that it will reach almost $50 million in 1985. Still, in-house research budgets of health and regulatory agencies may not increase so rapidly as in the past and could even dip. It is uncertain whether an increase in military spending will generate demand for chemicals in in-house armed services laboratories in amounts lost by other agencies. Thus government is a second market that suppliers say may not grow so fast as Kline predicts.

Hospitals will buy $28 million in laboratory chemicals this year, Kline estimates, for medical research, physician and nursing instruction, and clinical testing exclusive of diagnostic kits. This is 10% of the total market. Other laboratory types spend more than 40% of their money on inorganics and solvents, but hospital orders for these come to only about 30%. By contrast, hospital laboratories use one third of their laboratory chemicals budgets for radiochemicals, a much higher proportion than other laboratory types. Kline's projected growth rate of 4.7% per year would bring this market segment to almost $35 million in 1985.

In addition to these four laboratory markets for chemicals, a miscellaneous category of research foundations, consulting firms, high schools, and others will buy 6% of all laboratory chemicals this year, amounting to $18 million, according to Kline. Kline sees their purchases expanding at 4.7% yearly, which might bring this market segment to $22 million in 1985.

Although the laboratory chemicals market is relatively insulated from recessions, other factors have made

Laboratory organics show steady growth



Source: Industry estimates

Laboratories will buy $50 million worth of specialty organic chemicals in 1981, industry sources predict. Exact figures are hard to come by because of difficulties in gauging bulk sales for manufacture and repackaging. For example, consultant firm Charles H. Kline & Co. gives only $35 million as the size of the current laboratory market, growing at 4.6% per year.

Specialty organics cover a wide spectrum from best sellers like aniline or benzaldehyde to such esoteric academic reagents as bis(4-chlorophenyl)-diselenide. The category excludes common solvents, however, which most market analysts lump together with "inorganics."

About half of all organics are sold through distributors by such firms as J. T. Baker, Kodak, and MCB. The other half is sold directly, mostly by Aldrich. Fisher Scientific produces or purifies many organics for its own line and then sells them through its in-house distributor arm. Fluka of Buchs, Switzerland, bought a U.S. distributor, Tridom Chemical, Hauppage, N.Y., in January, and thus now also qualifies as a direct seller.

As Kline points out, organics have relatively long shelf lives and so are adaptable to sales through distributors. Companies selling through distributors generally limit their offerings to high-volume organics, whereas firms who sell direct see their greatest strengths in small sales of many compounds.

Exports of laboratory organics may be as much as $20 million annually, over and above the $50 million sold in the U.S. Aldrich alone exports about $8 million worth. Imports are only about $2 million to $3 million, though this figure could increase soon as Fluka becomes more aggressive in this country. Whereas the U.S. is one large market, served by nationwide distributors and direct sellers, American firms wishing to sell abroad usually must make arrangements with distributors, country by country. This has limited export efforts by some companies, though Aldrich and Alfa are two firms that have set up production and marketing branches outside the U.S.

In general, specialty organics are quite profitable. By buying and purifying industrial grades of high-volume organics in bulk, companies can multiply prices tenfold in packages of 3 kg and less. Firms that make their own synthetic and analytical reagents by chemical reaction add on a reasonable profit when selling them, though producers must keep an eye on one another's prices to stay competitive.

Catalog prices of such direct sellers as Aldrich are often much less than those for the same compounds sold through distributors. However, many customers find they pay comparable prices to both types of sellers. This is partly because companies that offer organic compounds in their line grant a 40% discount from catalog prices to distributors. Then, working with a high markup, distributors bidding on large sales of chemicals and apparatus can give discounts of 20% or more from list prices to laboratory customers. Storerooms that place periodic large orders thus may find organics prices comparable whether from distributors or direct sellers, whereas buyers needing small amounts may find it worthwhile to shop around. Still, when time is of the essence, persons placing small orders will choose the firm they know delivers fastest, regardless of price.

its growth uneven in the past 10 years. Some supplier firms have suffered more than others. For example, many laboratory chemicals were in short supply in 1973 and 1974, matching materials shortages in industrial chemicals. Industry observers say that this caused producers, distributors, and customers to build inventories. When interest rates topped 12% in the second half of 1974, making large inventories costly to maintain, a massive inventory draw-down produced a slump in the business.

Again, though inventories were not excessive in 1980, the march of interest rates past 20% in the first half caused many distributors to cut inventories, resulting in a leveling off of producer business in May. The current runup in interest rates past 20% shows no signs of letting up, putting further pressure on distributor inventories.

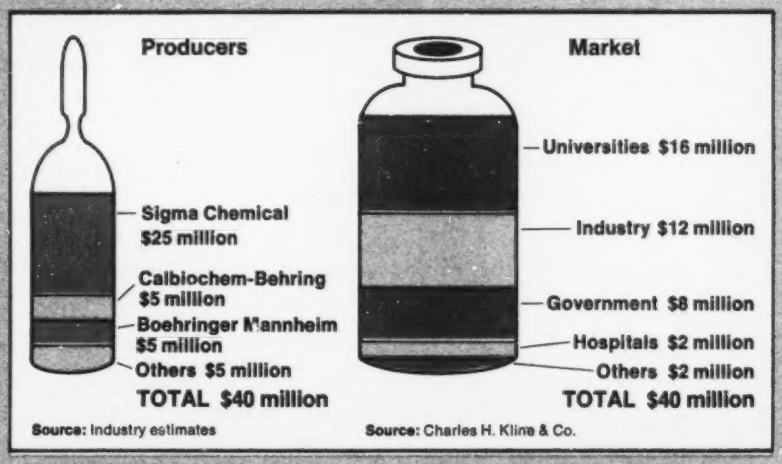
Laboratory chemical firms selling directly, or mostly, through large, nationwide distributors are said to have weathered these periods well. Companies selling largely through small, regional distributors may have lost business. The reason is that small distributors would be expected to be more susceptible to cash flow problems than large ones, moving them to deplete inventories more. Customers who could not get orders filled by their customary distributor might then turn to other sources rather than back-order, with possible loss of orders for some producer firms.

These economic forces added to the competition by many companies to serve a small market, have led firms to reassess their involvement in the business. This process will continue into the mid-1980's. In the past five years, many producers have trimmed catalog items about 25%, eliminating those selling less than a few hundred dollars per year.

At the same time, companies specializing in inorganics, solvents, and best-seller organics have developed solvents and reagents for newer instrumental methods as well as products for laboratory maintenance. The hope is that these new products will move customers to open that company's catalog preferentially and keep it open to complete their order.

One market variable on which there seems little inclination to compete is price discounts. Most producers are owned by large companies, whose managements demand a certain profit performance. In most areas

Life sciences research fuels biochemicals surge



Laboratory use of biochemicals was the strongest-growing segment of the laboratory chemicals business in the 1970's, with average yearly increases of 6%. For the 1980's, expansions of life sciences research in universities, hospitals, and government laboratories, and in many industrial firms will add to demand. Many companies are turning to the life sciences as the source of their next generation of products and services. Consultant firm Charles H. Kline & Co. predicts a growth of 7.8% per year through 1985.

The figure of $40 million for U.S. sales of laboratory biochemicals is approximate, because the number of firms supplying the market is large and because there are difficulties in defining the category. Some people say that amino acids and sugars are biochemicals, for example, while others see them as organics. As a second example, biological chemists routinely use tris buffer, which they buy often from biochemical suppliers, though others would consider it an organic. Products that seem definitely biochemicals include nucleic acids and oligonucleotides, enzymes, peptides and peptide hormones, carbohydrates, alkaloids, steroids, antibiotics, and vitamins.

Though increasing amounts of money are being invested in life sciences research, biochemicals producers cannot expect to garner more than a minute fraction of this. Biochemicals, item for item, are more costly than any other laboratory chemical category except radiochemicals, but they usually do not make up more than 3 to 5% of any budget.

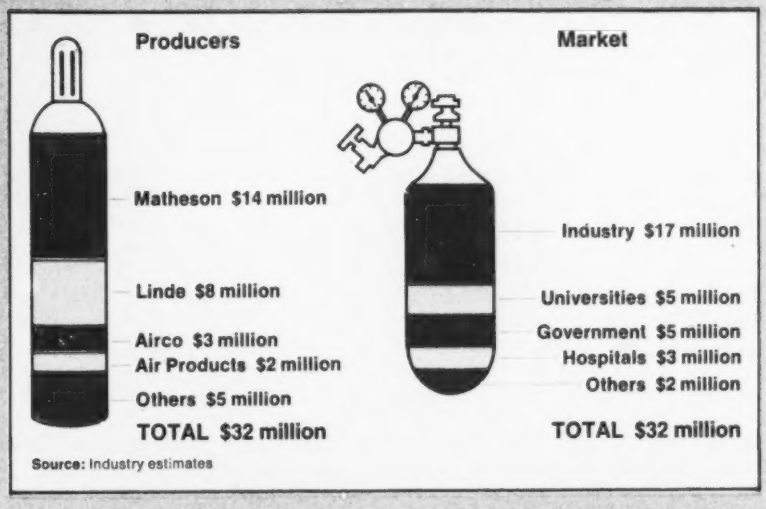
According to Kline, the short shelf life of biochemicals and attending problems of keeping inventories for extended periods result in 95% of biochemicals being sold direct rather than through distributors. Many must be shipped and stored refrigerated or frozen. In addition, sharp competition has showed profit margins below those for other laboratory chemical categories. Producers thus cannot offer 40% discounts to distributors that are standard for other types. Nevertheless, Kodak Laboratory Chemicals has announced plans to add biochemicals to its line in the next few years and will sell these through distributors.

U.S. biochemicals producers export about $20 million worth of their products, with Sigma Chemical Co., St. Louis, accounting for about $15 million. By contrast, foreign producers have been largely unsuccessful in penetrating the U.S. market. The exception is Boehringer Mannheim of Ingelheim, West Germany, which is thought to sell more than $5 million in the U.S.

Among companies that supply the U.S. biochemical market, Sigma is the leader with laboratory sales of $25 million a year. Calbiochem-Behring Corp., San Diego, and Boehringer Mannheim Biochemicals, Indianapolis, may each sell a little more than $5 million each. Other companies supplying the U.S. market include Miles Laboratories, Elkhart, Ind.; P-L Biochemicals, Milwaukee; and Worthington Biochemical Corp., Freehold, N.J. These figures do not include bulk sales of biochemicals destined to be included in clinical diagnostic kits, where the value of the biochemical is a small fraction of the kit's cost.

Academic laboratories buy $16 million worth of biochemicals, or 40% of the total, yearly, according to Kline. Sales to industrial labs are $12 million, and to government $8 million.

Gases have the lowest dollar market share



Source: Industry estimates

The 1981 U.S. market for laboratory gases is about $32 million, according to industry sources. Consultant firm Charles H. Kline & Co. predicts that sales in this category will increase at 5.8% annually through 1985.

Laboratory gases usually are purified grades of industrial gases and include oxygen, nitrogen, carbon dioxide, helium, argon, carbon monoxide, methane, chlorine, hydrogen sulfide, sulfur dioxide, ethylene, ammonia, nitrous oxide, and ethane, as well as liquid nitrogen and helium for cryogenic use in instruments and chemical reactions. There is also a small market for very accurately formulated gas mixtures for research and testing.

Almost 70% of laboratory gases are sold directly by such producer firms as Matheson Gas Products, East Rutherford, N.J.; Airco Industrial Gases, Murray Hill, N.J.; and Air Products & Chemicals, Allentown, Pa. A little more than 30% is sold through distributors by companies like Airco, Air Products, and Linde division of Union Carbide, South Plainfield, N.J.

Suppliers who sell directly to users say they have better control over cylinder rentals and returns. Gas producers that sell through distributors say such local firms can be more attentive to customer needs in their own regions. Laboratory gas distributors tend to be sellers of welding and other industrial gases who have added the capability to service the laboratory market. General chemical distributors also offer a limited number of gases in lecture bottles.

Among types of laboratories that use gases, industrial laboratories buy about 50 to 55% of the total. University and government laboratories each take about 15%. Approximately 10% goes to hospitals, while about 6% goes to other laboratories like research foundations and consulting firms.

of laboratory chemicals, no one seems to have wanted to be the first to start a price war.

According to the Kline study, 54% of laboratory chemicals are sold through distributors and 46% directly by producers. This marketing picture is not clear-cut, though. All "producers" of inorganics, solvents, and organics buy a large proportion of their compounds from one another to make up a well-rounded line before handing it over to distributors. These producers are thus themselves distributors of from one third to two thirds of their catalog items, repackaged under their own labels.

Selling through distributors lets original source companies eliminate large sales forces. Large source companies can limit themselves to 10 to 25 technically trained sales personnel, who concentrate on educating distributor salespeople on how to sell their line and on how to train chemists to use high-performance products.

Relying on distributors also lets source companies cut the number of warehouses to one to three. Source companies save on bookkeeping and shipping costs by shipping cases to distributors, who take on the task of filling customer orders bottle by bottle.

Distributors' own catalogs also produce more customer "pull-through." Through a single distributor, chemists can order many producers' chemicals, glassware, instruments, and other equipment. Company and university storerooms often send out periodic orders to several distributors for bids.

Selling through distributors has its headaches, though. Source companies must induce distributors to carry large enough inventories to give rapid delivery. Original suppliers still must put as many catalogs in the hands of chemists as possible. Distributors print apparatus catalogs but seldom have their own chemical catalogs. Suppliers also try to publish papers or present them at meetings to gain chemists' attention. Suppliers also exhibit at major meetings, advertise in print, and do direct mail advertising.

Moreover, pressures on inventories lead distributors with more than one chemicals line to think of whether they should divest themselves of all but one. In the past, many distributors would take on multiple chemical lines to have adequate product coverage. However, now that original source companies have filled out their lines, maintenance of more than one line by a distributor often is more a matter of tradition than good business sense.

Major original source companies for inorganics, solvents, and specialty organics include Aldrich Chemical Co., Milwaukee; J. T. Baker Chemical Co., Phillipsburg, N.J.; Fisher Scientific Co., Pittsburgh; Kodak Laboratory Chemicals, Rochester, N.Y.; Mallinckrodt, St. Louis; and MCB Reagents, Gibbstown, N.J.

Richardson-Merrell, which owns J. T. Baker, sold its pharmaceutical business to Dow Chemical in March. Though the new, surviving company, Richardson-Vicks, is oriented toward cosmetics and over-the-counter drugs, the management is confident about J. T. Baker's prospects in the laboratory chemicals business. The firm sells to this market only through distributors.

Paul E. Brunswick, J. T. Baker's marketing vice president for laboratory products, says the company decided some time ago that it was really in the analytical chemistry field. The company has moved into this field by offering high-purity solvents for high-performance liquid chromatography (HPLC) and spectroscopy, as well as equipment for thin-layer and flash chromatography. Noting that sample preparation is the forgotten art of analysis, Brunswick says the company recently has introduced a small column extraction system.

Laboratory organics: portrait of an entrepreneur

Unquestionably, the most colorful of the pioneers who built the laboratory organics industry was Max G. Gergel, who founded Columbia Organic Chemicals Co. in 1944 and retired from the firm in 1977. Here he is in his autobiography, "Excuse Me Sir, Would You Like to Buy a Kilo of Isopropyl Bromide?" getting a foot in the door at Du Pont:

"There was a problem. H. (the director of development) was impossible to see. He was surrounded by three concentric [rings] of secretaries who protected him from salesmen.

"I got through immediately by telling the first that I was Dr. H.'s natural son. In his sanctum, he listened carefully to my speech, in which I informed him that Du Pont was in serious trouble—that they had too many chemists. I proposed to help them by using my 'small, efficient company' to make the chemicals they needed at rock-bottom prices. He was interested and called in others . . . I told them too that Du Pont was in serious trouble . . . they nodded their heads in agreement without listening to the rest of my pitch.

"Dr. H. wanted to know if I was familiar with the synthesis of allene. . . . I told him that the best synthesis, to my knowledge, consisted of the dehydrochlorination of 1,2,3-trichloropropane, followed by treatment with a suspension of zinc in methyl alcohol to remove the remaining chlorine. He . . . suggested that we make it a joint project; we would dehydrochlorinate and they would dechlorinate. I told him that I would prefer it the other way around. He reminded me that I had told him that my visit was to make Du Pont's life easier; we agreed to run *both* reactions. My promise was complicated by the fact that I had never run either.

"When one treats 1,2,3-trichloropropane with alkali and a little water, the reaction is violent; there is a tendency to deposit the reaction product, the raw materials, and the apparatus on the ceiling and [on] the attending chemist. I solved this by setting up duplicate 12-liter flasks, each equipped with double reflux condensers, and surrounding each with a half dozen large tubs. In practice, when the reaction 'took off,' I would flee through the door or window and battle the eruption with water from a garden hose. The contents flying from the flasks were deflected by the ceiling and collected under water in the tubs. I used towels to wring out the contents [that] separated, shipping the lower layer to Du Pont. They complained of solids suspended in the liquid, but accepted the product and ordered more. I increased the number of flasks to four, doubled the number of washtubs, and completed the order.

"They ordered a 55-gallon drum. At best, with myself as chemist and supervisor, I could make a gallon a day, arriving home with skin and lungs saturated with 2,3-dichloropropene. I needed help. An advertisement in the local newspaper resulted in an interview with a former producer of illicit spirits named Preacher, who had just done penance at the local penitentiary.

"He listened carefully and approved of my method of production, which he said might be improved with copper coils. Immediately, he began to enlarge our production room by removing a wall, putting in an extra table, and increasing the number of washtubs and reaction setups. It was amazing to see Preacher in action (I gave him encouragement through the window) . . . he would walk up the aisles from setup to setup, putting in first the caustic, then the water, then fastening on the rubber stoppers and condensers, then using the hose. At this stage, the room was a swirling mass of steam and 2,3-dichloropropene. We made a vast amount of material and shipped the complete order to Du Pont—on schedule.

"As part of our contract with them, we had agreed to supply details of the production as well as innovations we might have discovered. I wrote them a complete description, giving credit to my indefatigable coworker. Two weeks later, I received a telegram with only two words: 'Ship Preacher!' "

Brunswick says the firm continually examines new laboratory technology for new product possibilities, with the hope not only of making money from these but also of drawing chemists into the rest of the catalog as well.

Students of the laboratory chemicals industry call Fisher Scientific a "captive distributor." That is, it is both producer and distributor. The company began producing chemicals for its own label in 1915, when German imports stopped reaching the U.S. Fisher also distributes the Kodak chemical line. Other companies have thought of acquiring Fisher for several years. In April, the firm rejected a takeover bid by Whittaker Corp., but Fisher management may be waiting for a better price from a more congenial prospect. In May, Tyco Laboratories bought 9% of Fisher stock but would not comment on ultimate takeover.

As its own in-house distributor, Fisher chemicals sales benefit from customer pull-through from a catalog of 80,000 items of apparatus. This catalog is designed to move its own line of 5000 chemicals, in addition to the almost 5000 compounds in the Kodak line.

In its role as original source company, Fisher develops new chemical products to lead customers to continue to order commodity-type laboratory chemicals. Chemical marketing manager Al Beranek says the firm is proud of having been the first to introduce HPLC solvents, for example.

MCB Reagents is a firm that has moved strongly to adjust to the more competitive market for laboratory chemicals since the mid-1970's. By 1977, G. D. Searle & Co. had decided that MCB no longer fit into its drug and health care business and ticketed the unit for divestment. E. Merck, Darmstadt, West Germany, bought MCB in April 1977.

For its 1981 catalog, MCB went through a long overdue housecleaning, trimming 1000 of its 3000 items that were no longer in demand and adding 200 new items. Then MCB moved its administration and marketing forces to new headquarters in Gibbstown, N.J., this January. Now the firm has plans to expand production and distribution facilities at its Cincinnati and Norwalk, Ohio, sites.

MCB sales director Jim Hall says the move from Searle to E. Merck ownership has sparked a more aggressive marketing stance, which includes distributor support and advertising. Among new products, designed to lure customers further into the catalog, are fluxes to prepare samples for x-ray fluorescence spectrometry, glass-distilled solvents for chromatographic and spectrometric techniques, and highly purified solvents for trace analyses. These efforts have gained MCB a 25% share in the $12 million annual market for performance solvents, second only to Burdick & Jackson Laboratories, Muskegon, Mich., which has a 50% share.

A small supplier with big ambitions is Alfa Products, Danvers, Mass., part of Ventron division of Thiokol. Founded in 1964 as a producer and repackager of uncommon inorganic

research chemicals, Alfa added common inorganics to its line. Then in 1979, Alfa added 6000 common and esoteric organic chemicals. Alfa became part of Thiokol when Thiokol bought Ventron in August 1976. With the addition of organic compounds, fleshing out its catalog to 10,000 items, Alfa is taking on such giants as Aldrich Chemical Co. and Kodak Laboratory Chemicals.

Alfa marketing manager Allan I. Stutz emphasizes that the company is a supplier of workhorse as well as esoteric compounds but admits that most chemists still think of Alfa as a source of uncommon inorganics. Both Alfa and Aldrich began as producers and suppliers of rare compounds, selling direct rather than through distributors. This origin gives both firms a research orientation as opposed to the largely marketing orientation of other companies.

Aldrich was founded in 1951 by Alfred R. Bader and merged with Sigma International in July 1975. Sigma is the leading U.S. producer of biochemicals. Bader has been for years a respected associate of eminent chemists. He spends a few days of each month traveling to laboratories around the country to find out what chemists would like to see offered in the catalog.

At both Alfa and Aldrich, research departments prospect for new product candidates by scanning the literature, inviting customer suggestions, and interviewing chemists. Stephen A. Fine, technical director for Alfa, says that this approach generates losers as well as winners. Among Alfa winners, for example, are ω-bromoalkyl isocyanates, often ordered as intermediates by medicinal chemists.

Fine cites as losers the two optical isomers, (+)- and (−)-isopropylidene- 2,3-dihydroxy- 1,4-bis(diphenylphosphine)butane (DIOP). Alfa chemists noted the use of DIOP to make asymmetric hydrogenation catalysts, devised an improved synthesis, and offered the two enantiomers in September 1980 at the relatively low price of $70 per gram. Sales didn't materialize and indeed dropped off with other sources who too offered DIOP. Chemists seem to have chosen that moment to abandon DIOP for other ligands for research on asymmetric hydrogenation catalysts.

The fate of losers differs at Aldrich and Alfa. When a newly offered compound doesn't sell well for two years at Alfa, the company advertises it on a list at fire sale prices. Fine says this technique often results in large sales. After that, Alfa writes off the compound and drops it from its catalog.

At Aldrich, by contrast, the loser compound is placed in a resource library of 35,000 such compounds. Though Aldrich still has costs from keeping such compounds in inventory, Bader says that the library pays for itself through later inquiries from customers. Chemists interested in locating, for example, homologous series of compounds for new drug lead testing, can order a computer-assisted search of the library and buy the compounds from Aldrich.

Another firm meeting competitive pressures by expanding its line is Kodak Laboratory Chemicals. Until this year, the company had been a producer and supplier mostly of organics. In March, Kodak unveiled the addition of 150 inorganic compounds, more than doubling the 100 inorganics the company has carried for several years in its catalog of 4500 items. Kodak spokesmen say that the 250 inorganics represent about 85% of the inorganic needs of chemists. The company also has announced plans to add a line of biochemicals in coming years.

Kodak's product additions point to a strategy to compete with such established original source companies for broad general lines as J. T. Baker, Fisher Scientific, Mallinckrodt, and MCB Reagents. The intended difference is that Kodak will have deeper coverage in organics and biochemicals than those firms. Like the other companies, Kodak sells only through distributors. Even so, Kodak actually has pruned its catalog as a result of marketing conditions that developed in the mid-1970's. From 1975 to 1978, the company whittled down its catalog of 6000 items to 4000, and now adds compounds selectively.

Like Fisher Scientific, Kodak also got into chemical production as a result of cutoffs of German imports in World War I, starting up in January 1919.

Another fairly early pioneer, not nearly so large, is Columbia Organic Chemicals Co., Columbia, S.C., founded in 1944. Columbia also has had to adjust to high inventory costs since the mid-1970's. Company president Stephen S. Reichlyn says he pared down the catalog from 10,000 to a little more than 5200 in 1977. Reichlyn also introduced cost accounting to achieve uniform pricing on the basis of realistic production costs. □

CHECKOFF

PLANTS COMPLETED

■ **Benzene sulfonyl chloride**—Jim Walter Resources' coke, iron, and chemicals division is opening new plant in Birmingham, Ala. Company says unit's capacity, at unspecified multimillion-pound level, will be enough to supply entire U.S. market. Product is used as agricultural intermediate, plasticizing component, and agent in production of corrosion inhibitors.

■ **Catalysts**—Davison Chemical subsidiary of W. R. Grace has started up unit in Baltimore to produce proprietary catalyst used in making Phillips-process high-density polyethylene. Expansion triples Davison's capacity for this catalyst from five years ago, when production first started.

■ **Industrial gases**—Airco has brought plant on stream in Bayport, Tex., with combined capacity of 330 tons per day of oxygen and nitrogen.

■ **Polyethylene, high-density**—Allied Corp. has started up 210 million lb-per-year expansion at Baton Rouge; project pushes Allied's total capacity to 670 million lb per year. Design engineering was by Crawford & Russell and prime construction contracting by Harmony Corp. of Baton Rouge and Davis Electric of Greenville, S.C.

■ **Specialty resins**—Ashland Chemical, part of Ashland Oil, has started up new $11 million, 50 million lb-per-year plant at Calumet City, Ill., to make resins used in foundry binders, paper coatings, adhesives, and other uses. Plant replaces facility destroyed by fire in mid-1978.

■ **Thionyl chloride**—Mobay Chemical has started up plant in Baytown, Tex., with capacity of 15 million lb per year for this intermediate used in making agricultural chemicals, drugs, and other specialties.

■ **Vitamin intermediates**—Hoffmann-La Roche is starting up 200 ton-per-day unit in Freeport, Tex., for chemicals used in making vitamins A and E.

Facts & Figures
for the chemical industry

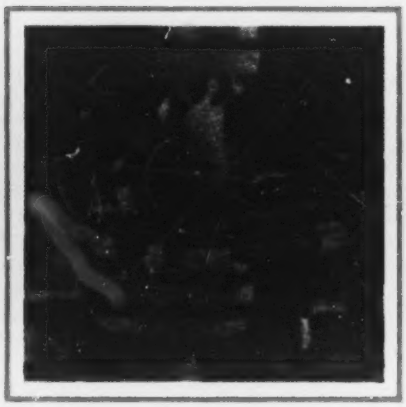
After four years of steady, if unspectacular, growth, the U.S. economy ran out of steam last year and U.S. chemical producers watched demand dwindle for most of their major product lines. Sales volumes, when measured by dollars, continued to grow as producers strived (not always successfully) to keep selling prices in pace with soaring operating costs. But plants were operating at reduced throttle. And the combination of high costs, lower output, and sagging productivity put a firm lid on profits. Some segments of the industry bucked the overall trend, to be sure, among them fertilizers and pharmaceuticals. All in all, though, it was a difficult, lackluster year for the U.S. chemical industry.

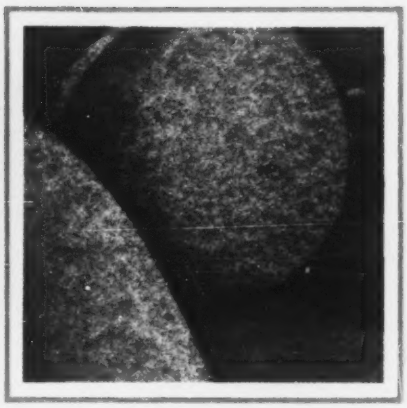
Nor was the malaise limited to the U.S. industry's home grounds. If anything, business was even poorer in much of Western Europe, while chemical operations slumped in Japan as well.

For the U.S. chemical industry, at least, 1980's midyear business slump was mercifully short-lived. During the second half of the year, the industry regained just about all the ground it had lost during the first six months. But demand remains far from robust this year in several key markets, such as automobiles and housing, and 1981 is not likely to register one of the industry's stellar performances. Nevertheless, this year's results are almost certain to stack up well when matched against the data for 1980 presented on the following pages of the 1981 edition of C&EN's annual report for the chemical industry.

Data published in Facts & Figures are collected from a variety of sources, among them government agencies, trade associations, international organizations, and the companies themselves that make up the industry. These data have been used to develop further information on growth rates, measures of performance, and other analytical comparisons to help to put the industry's recent performance in perspective.

Facts & Figures is made up of six sections. The first four of these deal specifically with the U.S. chemical industry, presenting statistics regarding production, financial results, operating performance, and employment. The fifth section deals with world trade in chemicals. The final section presents information on chemical industries outside of the U.S., covering Western Europe, Japan, Canada, Eastern Europe, China, and (for the first time) some data on the small but growing chemical operations in South Korea and Taiwan.





Facts & Figures at a glance

Section One: Production

Production of chemicals dropped sharply last spring in the U.S., dragging down output for 1980 as a whole about 5%. The decline was evident throughout almost all the industry's major product areas, with plastics down 10% and synthetic fibers off 8%. One product line that bucked the downtrend, however, was fertilizers, with increased demand helping to lift production of several fertilizer-related chemicals. **32**

Section Two: Finance

With selling prices, overall, averaging about 17% higher in 1980, chemical producers managed to increase their sales volume. The value of total shipments of chemicals and allied products rose 9%. But rising costs and depressed demand put a crimp in earnings for many companies. Chemical companies' spending on new plant and equipment in 1980 was strongly ahead of the previous year, but this year they are planning a much more modest increase. In contrast, the companies' increase of 17% in their R&D budgets last year is expected to be matched by a similar hike in 1981. **43**

Section Three: Performance

Last year's recession undercut productivity in the U.S. chemical industry, with output per manhour showing no improvement for the first time in more than a decade. And with production lower, plant operating rates were down during the latter part of the year to less than 70% of capacity. **65**

Section Four: Employment

The number of workers in the chemical industry dropped nearly 25,000 last spring and summer, but most of the lost jobs had been restored by early this year. For 1980 as a whole, employment in the industry was essentially unchanged from the year before. **69**

Section Five: Foreign trade

The value of chemical exports from the U.S. rose 20% last year, exceeding $20 billion for the first time. Imports of chemicals also increased, but not so fast, so that the surplus in U.S. chemical trade widened for the eighth year running. Total world trade in chemicals rose 12%, with the U.S. capturing a bigger slice of the total. **71**

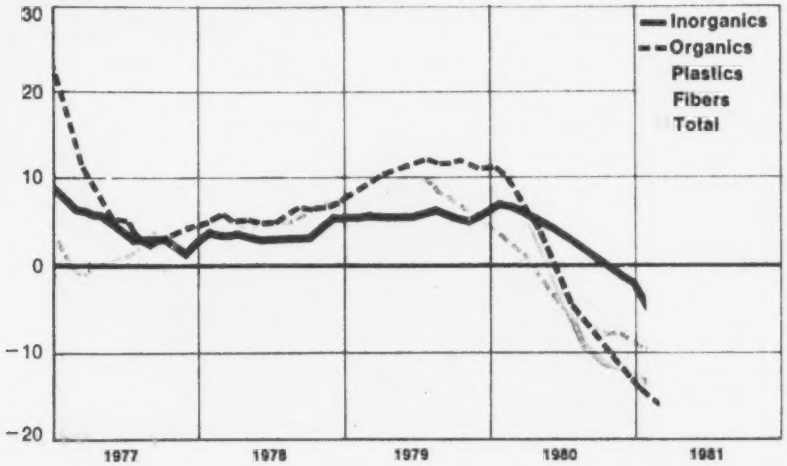
Section Six: Foreign chemical industries

Economic difficulties afflicted chemical producers throughout much of the world. In Western Europe, output of chemicals, plastics, and man-made fibers generally declined, and the majority of chemical companies were less profitable. In Japan, too, production faltered during the latter part of 1980 and profits were hard hit. On the other hand, the chemical business was better than ever in Canada, with expanding petrochemical operations contributing to a growing surplus in Canada's foreign trade in chemicals. Production of chemicals continued to grow in Eastern Europe, but at a relatively modest pace that fell below what had been targeted. **73**

Production of chemicals slumped in 1981

Growth rates for chemicals nosedived last year

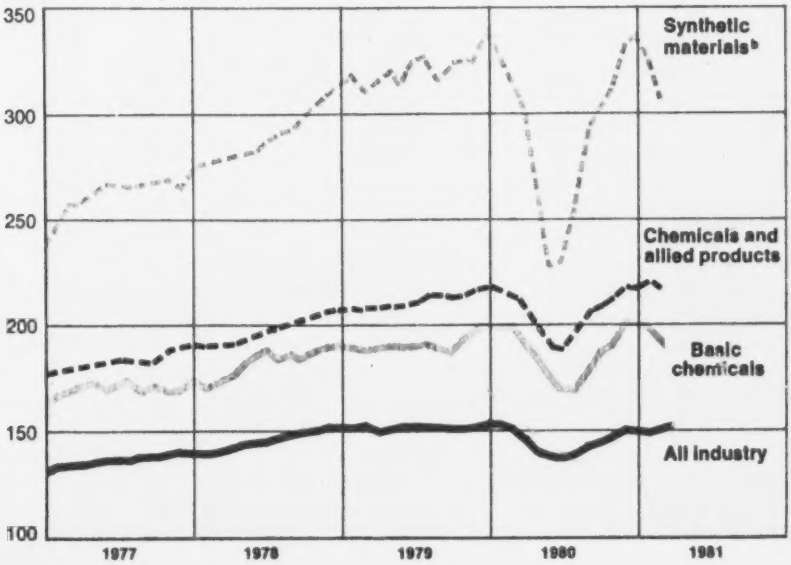
Production, % annual growth rate[a]



a Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. **Sources:** International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau

Chemical output snapped back from last year's recession

Production index,[a] 1967 = 100



a Seasonally adjusted. b Includes plastics, synthetic rubber, and man-made fibers.
Source: Federal Reserve Board

U.S. chemical plants were producing about the same volume of materials at the end of 1980 as they were when the year got started. In between, however, there was a sharp cutback that forced output of basic chemicals and synthetic materials down about 22% from February to July. As a result, production of these products for 1980 as a whole was off about 5% from the previous year, the first year-to-year decline since 1975.

Lower production was pervasive throughout almost all segments of the chemical industry. Plastics and resins were hard hit, for example, with thermosetting resins down 16% and the much bigger thermoplastics category falling 10% for the year as a whole. Among the big-volume thermoplastics, polystyrene and high-density polyethylene were both down 12%, and output of polyvinyl chloride sagged 11% below 1979's level.

Production of synthetic fibers totaled 8% less than in 1979, with sharp declines showing up for rayon and nylon. And synthetic rubber production collapsed a dismal 21%, with styrene-butadiene rubber, which accounts for just over half the total, falling 22%. Synthetic rubber output during 1980 was less than for any year in the past decade except 1975.

With output depressed for all these major polymers, organic chemicals also were under pressure. Output faltered almost across the board, with several important petrochemical products slipping 15 to 20% or more.

Inorganic chemicals were similarly beset, for the most part. Output of sodium hydroxide dropped 11%, for example, and chlorine 8%. The one notable exception to the general downturn shows up among inorganic chemicals used in making fertilizers, such as ammonia, ammonium nitrate, and sulfuric and phosphoric acids. Although fertilizer markets last year were not so buoyant as those of the year before, both domestic consumption and exports increased during the year.

TOP 50 CHEMICALS: Output fell last year, especially for organic chemicals

Rank 1980	Rank 1979[a]		Production: Billions of lb 1980	Billions of lb 1979	Common units[b] 1980	Common units[b] 1979	Average annual change 1979–80	1978–79	1975–80	1970–80
1	1	Sulfuric acid	80.69	83.98	40,343 tt	41,988 tt	−3.9%	2.2%	4.5%	3.2%
2	3	Ammonia	37.98	36.24	18,988 tt	18,121 tt	4.8	5.4	3.0	3.2
3	2	Lime[c]	35.36	38.78	17,681 tt	19,392 tt	−8.8	—	−0.5	−0.8
4	4	Oxygen	34.35	35.35	415 bcf	427 bcf	−2.8	−0.2	3.3	3.9
5	5	Nitrogen	34.20	29.93	472 bcf	413 bcf	14.3	5.4	13.3	12.1
6	6	Ethylene	27.54	29.90	27,544 mp	29,904 mp	−7.9	15.2	6.1	4.2
7	7	Sodium hydroxide	22.62	24.78	11,310 tt	12,392 tt	−8.7	15.7	3.4	1.1
8	8	Chlorine	22.38	24.22	11,190 tt	12,108 tt	−7.6	9.6	4.2	1.4
9	9	Phosphoric acid	21.71	20.27	10,857 tt	10,135 tt	7.1	8.3	7.2	6.7
10	12	Ammonium nitrate[d]	17.17	15.60	8,586 tt	7,800 tt	10.1	8.2	3.9	2.9
11	10	Nitric acid	17.09	17.13	8,544 tt	8,564 tt	−0.2	7.9	2.6	1.2
12	11	Sodium carbonate[e]	16.55	16.51	8,275 tt	8,253 tt	0.3	−0.4	3.0	1.6
13	14	Urea[f]	14.34	13.53	14,335 mp	13,534 mp	5.9	24.3	15.3	8.2
14	13	Propylene	13.71	14.20	13,711 mp	14,198 mp	−3.4	9.1	9.5	7.5
15	16	Toluene[g]	11.27	11.86	1,555 mg	1,636 mg	−5.0	55.2	17.1	6.5
16	15	Benzene	10.98	12.29	1,495 mg	1,672 mg	−10.6	12.4	7.8	2.8
17	17	Ethylene dichloride	9.97	11.79	9,974 mp	11,794 mp	−15.4	7.2	4.6	2.9
18	18	Ethylbenzene	7.61	8.45	7,609 mp	8,448 mp	−9.9	0.8	9.5	4.7
19	21	Carbon dioxide[h]	7.09	7.07	3,543 tt	3,533 tt	0.3	11.1	13.9	12.1
20	20	Methanol	7.00	7.37	7,002 mp	7,367 mp	−5.0	14.3	6.2	3.6
21	19	Styrene	6.90	7.48	6,897 mp	7,484 mp	−7.8	4.1	8.1	4.8
22	23	Vinyl chloride	6.46	6.39	6,458 mp	6,388 mp	1.1	−8.0	9.0	4.8
23	22	Xylene[g]	6.40	6.89	883 mg	950 mg	−7.1	12.4	6.7	5.1
24	24	Terephthalic acid[i]	5.92	6.16	5,924 mp	6,159 mp	−3.8	3.4	5.3	11.9
25	25	Formaldehyde[j]	5.77	5.97	5,768 mp	5,971 mp	−3.4	−6.4	4.8	2.7
26	26	Hydrochloric acid	5.50	5.95	2,750 tt	2,973 tt	−7.5	6.6	6.5	3.2
27	27	Ethylene oxide	4.95	5.67	4,951 mp	5,665 mp	−12.6	13.0	2.1	2.6
28	28	Ethylene glycol	4.24	4.73	4,243 mp	4,729 mp	−10.3	21.2	2.2	3.4
29	30	Ammonium sulfate	3.92	3.94	1,958 tt	1,971 tt	−0.7	1.4	−1.5	0.3
30	29	*p*-Xylene	3.83	4.65	3,829 mp	4,650 mp	−17.7	32.3	9.1	9.2
31	31	Cumene	3.16	3.92	3,161 mp	3,917 mp	−19.3	15.9	9.5	4.8
32	32	Butadiene[k]	2.89	3.58	2,894 mp	3,583 mp	−19.2	1.9	2.2	−0.7
33	34	Acetic acid	2.82	3.27	2,817 mp	3,265 mp	−13.7	17.7	5.1	3.8
34	33	Carbon black	2.55	3.33	2,546 mp	3,329 mp	−23.5	−0.5	−1.6	−1.4
35	39	Sodium sulfate[l]	2.51	2.35	1,257 tt	1,173 tt	7.2	0.4	0.5	−0.9
36	35	Phenol[m]	2.46	2.98	2,463 mp	2,981 mp	−17.4	11.1	7.2	3.7
37	37	Aluminum sulfate	2.36	2.46	1,182 tt	1,232 tt	−4.1	−5.9	0.7	−0.1
38	36	Acetone	2.12	2.65	2,123 mp	2,653 mp	−20.0	5.3	5.3	2.8
39	38	Cyclohexane	1.97	2.43	1,967 mp	2,425 mp	−18.9	4.0	2.6	0.7
40	43	Calcium chloride[n]	1.97	1.96	983 tt	981 tt	0.2	−4.8	−3.7	−1.2
41	42	Vinyl acetate	1.92	1.98	1,918 mp	1,982 mp	−3.2	17.1	8.2	9.1
42	41	Acrylonitrile	1.83	2.02	1,830 mp	2,018 mp	−9.3	15.2	8.5	5.8
43	44	Isopropyl alcohol	1.79	1.90	1,788 mp	1,900 mp	−5.9	9.8	3.3	−0.7
44	40	Propylene oxide	1.77	2.25	1,767 mp	2,249 mp	−21.4	9.9	3.0	4.2
45	46	Sodium silicate	1.48	1.55	740 tt	777 tt	−4.8	−2.4	0.4	1.6
46	48	Acetic anhydride	1.47	1.51	1,468 mp	1,505 mp	−2.5	0.3	0.6	−0.8
47	47	Sodium tripolyphosphate	1.44	1.51	719 tt	756 tt	−4.9	2.3	−1.4	−5.1
48	49	Titanium dioxide	1.43	1.48	715 tt	741 tt	−3.5	5.7	3.4	0.9
49	50	Ethanol[m]	1.22	1.41	1,224 mp	1,408 mp	−13.1	11.1	−3.0	−4.6
50	45	Adipic acid	1.20	1.80	1,200 mp	1,800 mp	−33.3	11.0	−2.2	1.0
		TOTAL INORGANICS IN TOP 50	**369.35**	**374.39**			**−1.3%**	**4.2%**	**4.0%**	**2.9%**
		TOTAL ORGANICS IN TOP 50	**173.51**	**189.03**			**−8.2%**	**13.8%**	**7.1%**	**4.5%**
		GRAND TOTAL OF TOP 50	**542.86**	**563.42**			**−3.6%**	**7.2%**	**5.0%**	**3.3%**

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons. c Except refractory dolomite. d Original solution. e Synthetic and natural. f Primary solution. g All grades. h All forms. i Includes both acid and ester without double counting. j 37% by weight. k Rubber grade. l High and low purity. m Synthetic only. n Solid and liquid.
Sources: Bureau of the Census, Bureau of Mines, International Trade Commission, C&EN estimates

PRODUCTION: Few increases show up in 1980's recession year

Industrial production indexes, 1967 = 100	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Total index	147.1	152.5	146.1	138.2	130.5	117.8	129.3	129.8	119.7	109.6	107.8	−4%	3%
Manufacturing, total	146.6	153.6	146.8	138.4	130.3	116.3	129.4	129.8	118.9	108.2	106.4	−5	3
Nondurable manufacturing	161.1	164.0	156.9	150.5	141.8	126.4	134.6	133.8	126.5	116.6	112.3	−2	4
Chemicals and products	206.7	211.8	197.4	185.7	170.9	147.2	159.4	154.5	143.6	125.9	120.4	−2	6
Chemicals and synthetic materials	222.1	234.2	216.7	201.1	185.1	154.1	176.7	171.9	156.4	135.8	126.9	−5	6
Basic chemicals	188.0	192.0	181.9	171.8	161.8	135.9	153.3	147.7	137.7	123.7	117.9	−2	5
Alkalies and chlorine	121.2	132.3	119.7	119.2	119.0	106.5	125.6	123.8	120.2	114.4	119.1	−8	0
Gases, coal tar, inorganic pigments	184.3	197.7	186.0	174.3	164.4	133.3	165.0	157.8	146.5	125.6	123.0	−7	4
Basic organic chemicals	233.0	233.3	221.2	204.7	189.8	155.3	177.9	170.0	155.3	139.7	128.7	0	6
Inorganic chemicals, nec	132.3	134.9	129.3	128.5	124.3	112.9	112.6	110.8	107.8	99.2	97.7	−2	3
Acids and fertilizer materials	145.9	142.0	133.6	124.2	117.6	108.4	116.6	113.1	111.5	150.3	106.2	3	3
Synthetic materials	291.5	320.1	287.6	260.8	232.5	191.0	224.4	221.1	194.7	160.4	145.1	−9	7
Plastics materials	382.6	420.1	366.5	320.3	280.1	213.1	258.5	243.3	217.4	166.2	155.7	−9	9
Synthetic rubber	103.1	130.5	127.5	124.5	118.7	101.2	129.7	135.6	126.9	117.2	114.8	−21	−1
Man-made fibers	250.1	270.8	250.9	236.8	214.3	191.2	214.4	220.1	189.1	164.9	142.2	−8	6
Chemical products	192.4	190.2	179.0	170.9	157.2	140.7	142.8	137.7	131.3	116.4	114.2	1	5
Drugs and medicines	245.7	238.2	220.6	213.9	191.5	174.1	179.6	170.1	155.5	135.1	127.5	3	7
Soap and toiletries	170.8	171.6	163.8	155.0	143.0	127.7	128.1	129.0	130.3	114.1	116.9	0	4
Paints	130.6	137.8	132.6	125.8	122.8	114.2	119.2	114.7	118.0	111.1	105.6	−5	2
Agricultural chemicals	230.5	221.6	211.8	201.1	185.4	163.9	144.6	127.0	108.9	103.5	107.9	4	8
Petroleum products	134.9	143.9	145.2	142.6	133.5	124.1	124.7	128.5	122.1	116.7	113.2	−6	2
Rubber and plastics products	255.8	272.2	253.6	232.3	199.7	166.7	195.2	184.1	172.4	147.6	132.3	−6	7

nec = not elsewhere classified. **Source:** Board of Governors of the Federal Reserve System

MINERALS: Changes in output last year generally were small

Thousands of tons	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Bromine, production	188[a]	249	223	217	230	204	216	209	193	178	175	−24%	1%
Iodine, consumption[b,c]	4.4	4.4	4.0	4.3	3.6	3.1	3.8	3.5	3.4	3.3	3.2	0	3
Imports[c]	3.1	3.1	3.4	3.5	3.2	2.7	4.0	3.1	3.1	3.6	3.0	0	0
Lime, production[d]	18,418[e]	20,983	20,484	19,987	20,257	19,159	21,645	21,132	20,332	19,635	19,788	−12	−1
Lithium, consumption[b,f]	3.0[e]	3.2	3.4	4.1	2.8	2.9	3.8	3.2	2.7	2.6	2.1	−6	4
Phosphate rock, marketable production	59,982	56,891	55,156	52,091	49,231	48,806	45,676	42,128	40,823	38,878	38,731	5	4
Exports	15,737	15,827	14,187	14,584	10,398	12,270	13,895	13,873	14,272	12,584	11,735	−1	3
Potash (K_2O equivalent),[g] production	2,468	2,453	2,484	2,457	2,400	2,501	2,552	2,603	2,659	2,587	2,729	1	−1
Imports[h]	5,481	5,693	5,189	5,076	4,594	3,797	4,326	3,587	2,961	2,766	2,605	−4	8
Apparent consumption	7,085	7,626	6,840	6,605	6,149	5,113	6,086	5,563	4,816	4,815	4,728	−7	4
Salt, total sold or used[i]	45,100[a]	45,820	42,896	43,439	44,218	41,057	46,565	43,939	45,051	44,106	45,928	−2	0
Evaporated	6,300[j]	6,248	5,872	5,704	5,634	5,372	5,951	5,913	5,879	5,956	5,530	1	1
Rock	14,400[j]	14,891	14,688	14,958	15,668	14,283	14,835	12,347	14,434	13,700	14,170	−3	0
Salt in brine[k]	24,400[j]	24,681	22,336	22,777	22,917	21,401	25,779	25,680	24,737	24,449	26,228	−1	−1
Sodium carbonate, production[l]	8,275	8,253	8,290	8,040	7,560	7,130	7,566	7,535	7,523	7,163	7,071	0	2
Sulfur, production[m]	13,050	13,339	12,318	11,824	11,992	12,610	12,789	12,231	11,444	10,730	10,703	−2	2
Apparent consumption[n]	15,030	15,145	13,889	12,850	12,060	11,875	12,115	11,463	11,036	10,274	10,334	−1	4
Frasch, production	7,044	7,007	6,226	6,520	7,016	8,077	8,849	8,518	8,165	7,868	7,932	1	−1
Recovered elemental, production	4,460	4,486	4,478	3,995	3,514	3,326	2,948	2,706	2,184	1,767	1,631	−1	11
Other, production	1,547	1,845	1,615	1,310	1,462	1,208	992	1,008	1,096	975	1,140	−16	3

a Estimated. b Estimated apparent consumption. c Crude elemental iodine. d Includes Puerto Rican production. e Preliminary. f Lithium content basis. g Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. h Includes nitrate of potash. i Total obtained by all recovery methods that was sold or used by domestic producers (figures differ slightly from U.S. production figures); figures include Puerto Rican production. j C&EN estimate. k Sold or used as such. l Natural and synthetic. m Sulfur content basis. n Calculated from shipments plus imports minus exports (sulfur content basis). **Source:** Bureau of Mines

ORGANIC CHEMICALS: Output drops almost all across the board

Millions of lb unless otherwise noted	Production											Annual change	
	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1979–80	1970–80
Acetic acid, synthetic	2,863	3,265	2,776	2,570	2,463	2,197	2,584	2,429	2,235	1,956	1,932	−12%	4%
Acetone	2,126	2,653	2,519	2,219	1,869	1,640	1,980	1,989	1,818	1,538	1,615	−20	3
Acrylonitrile	1,830	2,018	1,752	1,646	1,518	1,215	1,412	1,354	1,115	979	1,039	−9	6
Aniline	650	690	606	584	544	407	551	458	410	366	398	−6	5
Benzene, mg[b,c]	1,563	1,673	1,488	1,457	1,425	1,024	1,488	1,453	1,252	1,076	1,134	−6	3
Bisphenol A	525	576	471	455	449	293	370	320	255	187	202	−9	10
1,3-Butadiene[d]	2,934	3,583	3,515	3,259	3,507	2,597	3,682	3,644	3,527	3,340	3,101	−18	−1
Butanol	772	766	756	660	625	490	558	519	590	466	468	1	5
Caprolactam	905	945	919	867	780	713	668	656	640	575	na	−4	na
Carbon disulfide	376	448	476	505	508	479	782	777	768	753	721	−16	−6
Carbon tetrachloride	709	714	737	809	857	906	1,163	1,047	997	1,009	1,011	−1	−3
Cumene	3,162	3,917	3,380	2,644	2,716	2,003	2,906	2,665	2,293	2,144	1,983	−19	5
Cyclohexane	1,969	2,425	2,332	2,265	2,187	1,734	2,352	2,123	2,298	1,748	1,841	−19	1
Diisodecyl phthalate	122	175	171	161	143	106	147	171	153	136	123	−30	0
Dodecylbenzene[e]	563	627	526	526	529	495	533	498	524	550	553	−10	0
Ethanol, synthetic	1,238	1,408	1,267	1,339	1,496	1,429	1,618	1,962	1,851	1,630	1,957	−12	−4
Ethanolamines[f]	365	420	362	308	286	258	307	293	284	259	264	−13	3
Ethyl chloride	397	582	540	612	669	575	662	660	576	620	678	−32	−5
Ethylbenzene[g]	7,611	8,448	8,385	8,312	5,770	4,822	6,048	5,688	5,676	4,984	4,827	−10	5
Ethylene	27,760	29,904	25,955	25,172	22,475	20,499	23,891	22,329	20,852	18,450	18,089	−7	4
Ethylene dichloride	9,977	11,794	11,001	10,997	8,042	7,977	9,165[h]	9,293[h]	7,809	7,558	7,460	−15	3
Ethylene glycol	4,396	4,729	3,904	3,675	3,335	3,809	3,341	3,278	3,761	3,070	3,038	−7	4
Ethylene oxide	5,300	5,665	5,012	4,364	4,184	4,467	4,200[i]	4,167	3,962	3,598	3,865	−6	3
2-Ethylhexanol	285	318	420	493	450	387	395	402	526	287	457	−10	−5
Formaldehyde, 37%[j]	5,693	5,971	6,381	6,046	5,449	4,558	5,764	6,424	5,652	4,522	4,427	−5	3
Isopropyl alcohol	1,789	1,900	1,730	1,888	1,936	1,521	1,939	1,835	1,790	1,674	1,919	−6	−1
Maleic anhydride	298	323	341	294	264	216	290	282	274	229	215	−8	3
Methanol, synthetic	7,064	7,367	6,443	6,453	6,242	5,176	6,878	7,064	6,472	4,950	4,932	−4	4
Methyl chloride	348	463	454	476	378	366	493[h]	544[h]	454	437	423	−25	−2
Methyl ethyl ketone	591	656	661	512	428	425	506	541	509	484	480	−10	2
Methyl chloroform	na	716	644	635	631	459	592	548	441	375	366	na	na
Methylene chloride	564	633	570	478	538	497	609	520	471	401	402	−11	3
Perchloroethylene	769	773	725	614	669	679	734	706	734	705	707	−1	1
Phenol, synthetic[k]	2,463	2,981	2,682	2,338	2,121	1,746	2,298	2,241	2,052	1,744	1,708	−17	4
Phthalic anhydride	857	1,013	978	926	902	702	977	1,023	933	794	734	−15	2
Propylene[c]	13,792[l]	14,198[l]	13,014[l]	13,328[l]	10,030[l]	8,709[l]	10,475[m]	9,884[m]	8,472[m]	6,891[m]	6,641[m]	−3	8
Propylene glycol	na	610	547	489	517	391	510	502	563	421	428	na	na
Propylene oxide	1,767	2,249	2,047	1,866	1,823	1,524	1,756	1,753	1,520	1,194	1,179	−21	4
Styrene, monomer	6,904	7,484	7,186	6,867	6,301	4,673	5,956	5,975	5,941	4,682	4,335	−8	5
Terephthalic acid, dimethyl ester[n]	5,995	6,159	5,954	5,410	5,051	4,614	4,262	2,564[o]	4,405[p]	3,574	2,989	−3	7
Toluene, mg[b,c]	na	1,010	1,054	1,018	999	705	922	958	916	876	830	na	na
Vinyl acetate	1,921	1,982	1,692	1,586	1,481	1,290	1,403	1,503	1,211	931	803	−3	9
Vinyl chloride	6,471	6,389	6,941	5,986	5,677	4,196	5,621	5,351	5,089	4,336	4,040	1	5
***o*-Xylene**	997	1,082	1,013	985	854	703	1,056	1,068	832	785	799	−8	2
***p*-Xylene**	3,829	4,650	3,516	3,172	2,911	2,484	2,707	2,526	2,208	1,662	1,590	−18	9

a Preliminary figures. b Tar distillers not included to avoid disclosing individual company data; includes material for use in blending motor fuels. c All grades. d Rubber grade. e Includes straight-chain dodecylbenzene, tridecylbenzene, and other straight-chain alkylbenzenes. f Mono-, di-, and triethanolamines. g Does not include ethylbenzene produced and consumed in continuous-process styrene manufacture. h Production figure may be too low, because some methyl chloride and ethylene dichloride were produced but not separated or accurately measured by some producers. i Approximate figure. j By weight. k Does not include data for coke ovens and gas retort ovens. l Includes refinery propylene. m Includes data for propane-propylene mixture. n Includes both the acid and its dimethyl ester (DMT), without double counting; acid figures multiplied by 1.16 to convert to equivalent DMT. o Includes only dimethyl ester and not acid. p Figure may be too high because of possible double counting of some acid and ester. na = not available. **Source:** International Trade Commission

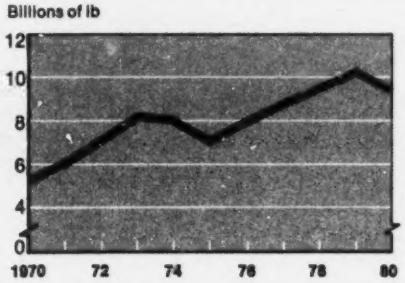
INORGANICS: Output in 1980 was a mixed pattern of increases and declines

Thousands of tons unless otherwise noted	Production											Annual change	
	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1979–80	1970–80
Aluminum sulfate[b]	1,182	1,314	1,309	1,255	1,202	1,146	1,257	1,233	1,193	1,127	1,191	−10%	0%
Ammonia,[c,d] 100%	19,044	18,523	17,119	17,765	16,716	16,419	15,733	15,208	15,169	14,538	13,824	3	3
Ammonium nitrate,[e] 100%	8,590	7,543	7,210	7,177	7,186	7,088	7,542	7,235	6,863	6,635	6,456	14	3
Ammonium sulfate,[d,f] 100%	na	2,363	2,449	2,264	2,010	2,106	2,120	1,987	1,858	1,821	1,894	na	na
Carbon dioxide[g]	3,545	3,124	3,001	2,610	2,064	1,850	1,804	1,566	1,610	1,344	1,135	13	12
Chlorine gas[h]	11,195	12,228	11,052	10,573	10,378	9,167	10,753	10,402	9,854	9,352	9,764	−8	1
Hydrochloric acid,[i] 100%	2,751	3,090	2,793	2,668	2,542	2,009	2,470	2,534	2,360	2,099	2,014	−11	3
Hydrogen,[j,k] bcf, 100%	96	99	90	85	82	74	82	65	59	56	60	−3	5
Nitric acid,[l] 100%	8,733	8,465	7,934	7,987	7,791	7,527	8,120	8,398	7,981	7,638	7,603	3	1
Nitrogen gas,[j,m] bcf, 100%	473	427	379	328	289	252	243	227	194	168	151[n]	11	12[o]
Oxygen,[j,m] bcf, 100%	415	457	430	392	388	353	390	389	352	319	284[n]	−9	3[o]
Phosphoric acid, 100% P_2O_5	10,856	10,317	9,637	8,745	7,949	7,677	7,213	6,927	6,712	5,970	5,683	5	7
Phosphorus[p]	432	460	441	430	437	450	524	526	541	545	597	−6	−3
Sodium hydroxide, 100%	11,309	12,772	11,309	11,000	10,516	9,635	11,189	10,734	10,216	9,667	10,141	−11	1
Sodium phosphate[q]	719	758	739	717	724	770	903	967	1,033	1,040	1,208	−5	−5
Sodium silicate[r]	739	770	829	760	747	724	770	723	661	636	628	−4	2
Sodium sulfate,[s] 100%	1,259	1,115	1,168	1,199	1,232	1,227	1,348	1,437	1,327	1,356	1,373	13	−1
Sulfuric acid,[t] 100%	43,888	43,118	41,314	38,337	34,878	32,360	33,936	31,949	31,183	29,035	29,525	2	4
Titanium dioxide,[u] 100%	714	741	701	687	713	603	787	785	693	678	655	−4	1
Urea, 100%	7,218	7,027	6,273	5,072	4,498	3,799	3,789	3,543	3,467	3,125	3,119	3	9

a Preliminary. b Commercial, 17% Al_2O_3; includes municipalities except in 1980. c Synthetic anhydrous. d Excludes by-product ammonia liquor and ammonium sulfate. e Original solution. f Synthetic and noncoke by-product. g Solid, liquid, and gas; excludes quantities produced and consumed in plants making soda ash or urea, and quantities produced and transferred to other plants for further processing. h Includes quantities liquefied for use, storage, or shipment. i Includes anhydrous hydrochloric acid production. j High- and low-purity gas. k Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. l Includes unspecified amounts of nitric acid produced but not withdrawn from the system. m Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. n High-purity gas only. o Annual change for 1971–80. p Elemental, white (yellow), and red. q Tripolyphosphate (100% $Na_5P_3O_{10}$). r Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. s Anhydrous, high and low purity, and Glauber's salt. t Gross (new and fortified). u Composite and pure. **Note:** bcf = billions of cubic feet; na = not available. **Sources:** Department of Commerce, International Trade Commission

MAN-MADE FIBERS: U.S. output dropped last year for first time since 1975

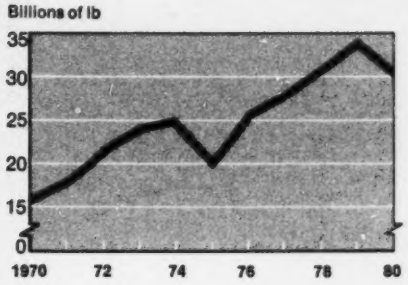
Man-made fibers production



Millions of lb	Production											Annual change	
	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1979–80	1970–80
CELLULOSIC FIBERS													
Acetate[a]	316	324	308	290	298	313	382	462	429	476	498	−2%	−4%
Rayon	490	606	587	598	543	436	817	895	965	915	875	−19	−6
NONCELLULOSIC FIBERS													
Acrylic[b]	779	761	726	709	621	525	631	742	626	545	492	2	5
Nylon[c]	2358	2,720	2550	2326	2075	1857	2124	2175	1974	1595	1355	−13	6
Olefins[d]	748	759	692	635	577	497	531	492	416	322	262	−1	11
Polyester	3989	4,178	3800	3642	3340	2995	2926	2888	2328	1142[e]	1022[e]	−5	na
Textile glass	867	1,014	923	787	676	546	683	688	572	468	467	−14	6
Other	19[f]	18[f]	16[f]	16[f]	14[f]	12[f]	12[f]	13[f]	11[f]	688[g]	455[g]	6	na
TOTAL	**9566**	**10,381**	**9611**	**9002**	**8144**	**7181**	**8105**	**8354**	**7322**	**6152**	**5427**	**−8%**	**6%**

a Includes diacetate and triacetate; excludes production for cigarette filtration. b Includes modacrylic. c Includes aramid. d Includes olefin yarn and monofilaments, and olefin and vinyon staple and tow. e Does not include yarn and monofilaments. f Includes only yarn and monofilaments; yarn is chiefly saran and spandex. g Includes only yarn and monofilaments; yarn includes polyester, anidex, saran, spandex, vinyon, and TFE fluorocarbon. na = not available. **Source:** Textile Economics Bureau

Plastics production



PLASTICS: Output was lower in 1980, especially for thermosets

Millions of lb[a]	Production 1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	1970–80[b]
THERMOSETTING RESINS													
Epoxy[c]	315	361	299	261	244	198	249	223	184	165	165	−13%	7%
Polyester[d]	947	1,147	1,209	1,061	1,042	834	911	1,051	933	730	569	−17	5
Urea	1,165	1,367	1,122	963	821	690	835	867	739	636	746	−15	6
Melamine	167	200	202	200	186	115	164	170	171	168		−16	
Phenolic[e]	1,499	1,781	1,617	1,458	1,340	1,051	1,335	1,387	1,453	1,194	1,186	−16	2
TOTAL	**4,094**	**4,857**	**4,448**	**3,943**	**3,631**	**2,888**	**3,494**	**3,698**	**3,481**	**2,893**	**2,666**	**−16%**	**4%**
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	7,291	7,793	7,111	6,471	5,813	4,743	5,973	5,803	5,274	4,458	4,240	−6	6
High density[g]	4,405	5,010	4,201	3,652	3,125	2,468	2,837	2,637	2,325	1,924	1,604	−12	11
Polypropylene	3,648	3,841	3,074	2,747	2,632	1,902	2,249	2,162	1,726	1,288	1,031	−5	13
Acrylonitrile-butadiene-styrene	920	1,191	1,134	1,069	988	642	857	877	810	686[h]	568	−23	6
Styrene-acrylonitrile	111	124	120	115	113	109	109	121	99	77[h]		−10	
Polystyrene[i]	3,521	4,005	3,823	3,446	3,195	2,662	3,364	3,322	3,[illegible]9	2,553	2,371	−12	4
Styrene-butadiene copolymers and other styrene resins	785	916	878	813	756	585	679	703	624	433	611	−14	3
Polyamide, nylon type	274	327	275	254	247	135	204	205	157	110[h]	91	−16	12
Polyvinyl alcohol	141	148	127	119	123	118	142	96	62	58[h]	49	−5	11
Polyvinyl chloride and copolymers	5,470	6,119	5,723	5,253	4,716	3,648	4,850	4,562	4,259	3,471	3,115	−11	6
Other vinyl resins[j]	196	220	197	197	225	187	209	199	194	167[h]	170	−11	1
TOTAL	**26,762**	**29,694**	**26,663**	**24,136**	**21,933**	**17,199**	**21,473**	**20,687**	**18,669**	**15,225**	**13,850**	**−10%**	**7%**

a Dry weight basis. b Annual change calculated for 1970–80 is approximate, because figures from Society of the Plastics Industry for 1980 and International Trade Commission for 1970 are not completely comparable. c Unmodified. d Unsaturated. e Includes other tar acid resins. f 0.940 density and below. g Density above 0.940. h Figure from International Trade Commission. i Dry resin content. j Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene chloride. **Sources:** Society of the Plastics Industry, for years 1971 to 1980, and International Trade Commission for 1970

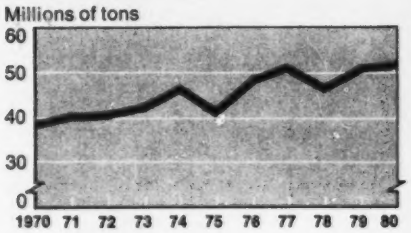
SYNTHETIC RUBBER: Production plummeted last year across the board

Thousands of metric tons	Production 1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	1970–80
Styrene-butadiene rubber[a]	1074	1378	1395	1395	1333	1179	1466	1537	1500	1439	1352	−22%	−2%
Polybutadiene	311	397	378	361	352	290	310	337	299	258	284	−22	1
Nitrile	63	75	73	70	73	55	88	84	75	66	68	−16	−1
Ethylene-propylene	144	175	174	158	130	84	126	120	91	61	64	−18	8
Polychloroprene	151	183	161	165	165	144	163	na	na	na	na	−17	na
Butyl		194	154	149	125	80	164	160	131	108	120	−18	−1[e]
Polyisoprene				62	74	61	93	119	134	118	122		
Other[c]	266[b]	132[b]	138[b]	56	51	47	88	270[d]	226[d]	226[d]	221[d]		
TOTAL	**2009**	**2534**	**2475**	**2418**	**2304**	**1941**	**2498**	**2627**	**2456**	**2278**	**2232**	**−21%**	**−1%**

a Excludes high-styrene latex (more than 45% styrene). b Includes butyl rubber in 1980 and polyisoprene in 1978–80. c Excludes polyurethane rubber. d Includes polychloroprene (neoprene). e Annual change for 1970–80 calculated by comparing polychloroprene plus butyl rubber, polyisoprene, and other in 1980 with butyl, polyisoprene, and other (including polychloroprene) in 1970. **na** = not available. **Sources:** Rubber Manufacturers Association, Department of Commerce

1 PRODUCTION BY THE U.S. CHEMICAL INDUSTRY

Fertilizer consumption



Note: Years ending June 30.
Source: Department of Agriculture

FERTILIZERS: U.S. output is higher, with nitrogen products leading the way . . .

Thousands of tons	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
NITROGEN (N)													
Domestic production	12,323	11,106	10,466	10,789	10,572	9343	10,094	9447	8971	8924	8321	11%	4%
Imports	2,566	2,165	1,866	1,842	1,218	1198	1,068	882	843	929	855	19	12
Exports	2,638	2,468	1,778	1,251	1,239	1115	1,269	1508	1032	1077	1328	7	7
Domestic supply	12,251	10,803	10,554	11,380	10,551	9426	9,893	8821	8782	8776	7848	13	5
PHOSPHATE (P_2O_5)													
Domestic production	10,012	9,432	8,245	7,793	7,199	7230	6,869	6387	6150	5736	5520	6	6
Imports	239	236	229	245	221	274	315	312	326	283	273	1	−1
Exports	3,925	3,848	3,290	2,501	2,175	1860	1,581	1422	1102	898	845	2	17
Domestic supply	6,326	5,820	5,184	5,537	5,245	5644	5,603	5277	5374	5121	4948	9	2
POTASH (K_2O)													
Domestic production	2,474	2,519	2,176	2,584	2,313	2287	2,604	2690	2432	2490	2430	−2	0
Imports	5,403	5,085	4,948	4,955	3,910	3847	4,114	3192	3088	2510	2646	6	7
Exports	1,048	999	1,003	994	911	848	947	922	657	620	681	5	4
Domestic supply	6,829	6,605	6,121	6,545	5,312	5286	5,771	4960	4863	4380	4395	3	5

. . . as farmers up their use of plant nutrients modestly

Thousands of tons	Consumption 1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
TYPE													
Mixed fertilizer	23,232	23,742	22,110	24,099	22,958	20,647	24,067	22,547	21,511	21,513	20,961	−2%	1%
Primary nutrient material	27,136	25,600	23,511	24,999	23,935	19,959	20,897	19,275	18,385	18,389	17,331	6	5
Secondary and micronutrients	2,269	2,139	1,877	2,525	2,296	1,878	2,130	1,466	1,310	1,216	1,297	6	6
TOTAL	**52,637**	**51,481**	**47,497**	**51,624**	**49,189**	**42,484**	**47,094**	**43,288**	**41,206**	**41,118**	**39,589**	**2%**	**3%**
PRIMARY NUTRIENT CONTENT													
Nitrogen (N)	11,400	10,715	9,965	10,647	10,412	8,601	9,157	8,295	8,022	8,134	7,459	6	4
Phosphate (P_2O_5)	5,391	5,606	5,096	5,630	5,228	4,507	5,099	5,085	4,864	4,803	4,574	−4	2
Potash (K_2O)	6,161	6,244	5,526	5,834	5,210	4,453	5,083	4,649	4,327	4,231	4,036	−1	4
TOTAL	**22,952**	**22,565**	**20,587**	**22,111**	**20,849**	**17,561**	**19,338**	**18,029**	**17,213**	**17,168**	**16,068**	**2%**	**4%**

Note: Years ending June 30. **Source:** Department of Agriculture

NITROGEN OUTPUT: Urea's share up

Thousands of tons (N)	1980	1979	1978	1970	Change 1979–80
Ammonia[a]	5,270	4,603	4,063	3893	14%
Ammonium nitrate[b,c]	1,096	1,137	1,044	1122	−4
Urea	1,572	1,201	1,001	547	31
Ammonium sulfate[c]	521	509	497	483	2
All other	3,864	3,656	3,861	2276	6
TOTAL	**12,323**	**11,106**	**10,466**	**8321**	**11%**

a Includes aqueous solutions. b Includes ammonium nitrate-limestone mixtures. c Adjusted for estimated quantity going into nonfertilizer uses. **Note:** Years ending June 30. **Source:** Department of Agriculture

PHOSPHATE OUTPUT: Up 6% in 1980

Thousands of tons (P_2O_5)	1980	1979	1978	1970	Change 1979–80
Ammonium phosphate[a]	5,519	5082	4548	1957	9%
Concentrated superphosphate	1,737	1901	1768	1395	−9
Normal and enriched superphosphate	384	320	303	766	20
All other	2,372	2129	1626	1402	11
TOTAL	**10,012**	**9432**	**8245**	**5520**	**6%**

a Liquid and solid, excluding that combined with potash salts in process of manufacture.

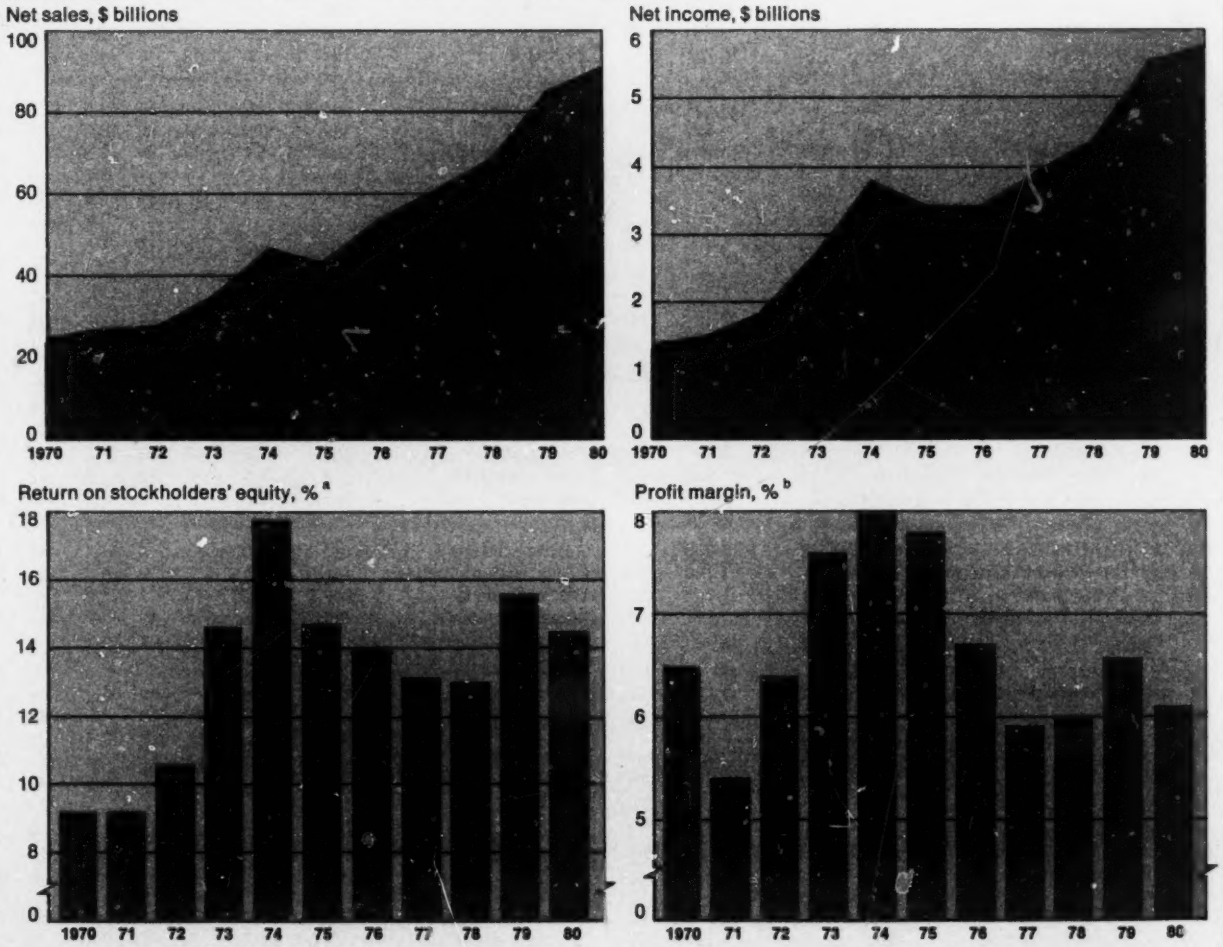
Prices push sales higher but profits stagnate

The 1980 recession caught up with the U.S. chemical industry, but in general the industry weathered the storm with relatively little damage—especially compared to several other segments of the national economy, or for that matter with its own results during the previous recession of 1975. It held up, also, better than many industry analysts had been forecasting as the storm clouds gathered at the year's start.

For one thing, sales continued to expand. The credit for that, however, rests entirely on increased prices for most product lines. With a few exceptions, such as fertilizers, the physical volume of sales was depressed. Nevertheless, despite lower plant operating rates and high costs for feedstocks and credit, earnings held up surprisingly well. And although measures of profitability reflect the pressures of a depressed economy, they too did not decline quite so severely as during previous business downturns.

It is noteworthy, however, that the chemical industry's profitability never did regain the levels the industry enjoyed prior to the 1975 recession during the long recovery period of 1976–79. Consequently, profit margins in particular do not stack up very favorably against those of the early 1970's.

Earnings continued to rise last year but were crimped by slower sales growth, putting a dent in chemical companies' profitability



a After-tax earnings as percentage of stockholders' equity. b After-tax earnings as percentage of net sales. **Note:** Data based on annual figures of 40 largest industrial chemical companies.

TOP 50 CHEMICAL PRODUCERS: **Almost half are not primarily part of the chemical industry**

Rank 1980	Rank 1979[a]	Company	Chemical sales 1980 ($ millions)	Change from 1979	Total sales 1980 ($ millions)	Chemical sales as % of total sales	Industry classification	TOTAL COMPANY: Net income 1980 ($ millions)	Profit margin[b] Per cent 1980	Profit margin[b] Rank 1980	Profit margin[b] Rank 1979	Return on stockholders' equity[c] Per cent 1980	Return on stockholders' equity[c] Rank 1980	Return on stockholders' equity[c] Rank 1979
1	1	Du Pont	$10,250	6%	$ 13,652	75%	Basic chemicals	$ 706	5.2%	27	14	12.6%	34	17
2	2	Dow Chemical	7,217	9	10,626	68	Basic chemicals	805	7.6	12	8	18.1	17	8
3	3	Exxon	6,936	19	103,143	7	Petroleum	5650.1	5.5	23	30	22.2	7	11
4	4	Union Carbide	5,650	7	9,994	57	Basic chemicals	673	6.7	15	23	14.1	29	35
5	5	Monsanto	5,453	5	6,574	83	Basic chemicals	148.8	2.3	44	31	5.3	46	41
6	6	Celanese	3,200	6	3,348	96	Basic chemicals	122	3.6	41	37	11.1	40	36
7	7	Shell Oil	3,089	19	19,830	16	Petroleum	1542	7.8	11	12	19.0	15	26
8	9	W. R. Grace	2,733[d]	14	6,101	45	Specialty chemicals	283.8	4.7	34	38	15.8	23	34
9	8	Gulf Oil	2,569[d]	5	26,483	10	Petroleum	1407	5.3	26	29	14.6	26	30
10	13	Occidental Petroleum	2,458[d]	23	12,476	20	Petroleum	710.8	5.7	20	27	31.2	3	1
11	10	Allied Corp.	2,450	14	5,519	44	Basic chemicals	289	5.2	27	39	15.0	25	40
12	12	Standard Oil (Ind.)	2,235	11	26,133	9	Petroleum	1915.3	7.3	13	10	20.4	12	16
13	11	Hercules	2,095	3	2,485	84	Basic chemicals	114.0	4.6	36	15	11.3	38	15
14	16	Atlantic Richfield	1,945	17	23,744	8	Petroleum	1651.4	6.8	14	16	22.2	8	11
15	14	American Cyanamid	1,861[d]	10	3,454	54	Basic chemicals	159.2	4.6	35	32	11.1	39	39
16	15	Phillips Petroleum	1,858	10	13,377	14	Petroleum	1069.6	8.0	10	6	21.7	10	7
17	17	Eastman Kodak	1,837	17	9,734	19	Photographic equipment	1153.6	11.9	3	2	19.1	14	14
18	19	Stauffer Chemical	1,643	11	1,695	97	Basic chemicals	136.6	8.1	9	7	14.6	27	27
19	18	Rohm & Haas	1,608	9	1,725	93	Basic chemicals	93.7	5.4	24	24	13.3	31	32
20	22	Tenneco	1,565	11	13,226	12	Petroleum	726	5.5	22	33	15.2	24	28
21	23	Mobil	1,558	18	59,510	3	Petroleum	281.3	4.7	32	36	21.5	11	13
22	20	Borden	1,548[d]	6	4,596	34	Dairy products	147.9	3.2	42	42	12.0	35	42
23	21	Ethyl Corp.	1,517[d]	5	1,741	87	Basic chemicals	89.7	5.2	29	26	12.8	33	31
24	25	U.S. Steel	1,437	19	12,492	12	Steel	458.9	3.7	40	—	8.7	43	—
25	28	Texaco	1,346	29	51,196	3	Petroleum	2240.2	4.4	37	34	17.9	18	24
26	24	Diamond Shamrock	1,307	6	3,143	42	Basic chemicals	201.2	6.4	18	13	16.2	22	19
27	27	Air Products[e]	1,262	19	1,421	89	Basic chemicals	115.5	8.1	8	11	17.4	20	20
28	32	CF Industries	1,233[d]	21	1,233	100	Agricultural chemicals	187.3[f]	15.2	1	3	38.7	1	2
29	26	FMC	1,215	7	3,482	35	Farm and construction machinery	142.7	4.1	38	35	11.5	37	38
30	36	Williams Cos.	1,171[d]	28	2,073	57	Agricultural chemicals	138.7	11.8	4	41	14.4	28	44
31	30	Standard Oil of Calif.	1,155	11	40,479	3	Petroleum	2401	5.9	19	25	21.7	9	9
32	38	Ciba-Geigy	1,115	32	1,690	66	Specialty chemicals	na	na	—	—	na	—	—
33	33	Ashland Oil	1,100	8	8,118	14	Petroleum	205.1	2.5	43	43	17.6	19	18
34	35	Mobay Chemical	1,069	12	1,069	100	Basic chemicals	54.1	5.1	30	22	13.0	32	22
35	37	Union Oil of Calif.	1,048	21	9,984	10	Petroleum	647.0	6.5	17	18	18.6	16	21
36	31	B. F. Goodrich	1,022	−2	3,080	33	Rubber products	61.7	2.0	45	44	6.4	45	45
37	43	International Minerals[g]	974	24	1,790	54	Agricultural chemicals	145.9	8.2	7	9	16.6	21	29
38	34	PPG Industries	964	−1	3,158	31	Glass products	209.2	6.6	16	17	13.9	30	25
39	29	BASF Wyandotte	917	−12	917	100	Basic chemicals	(65.1)[h]	—	—	48	—	—	47
40	45	Lubrizol	902	24	902	100	Specialty chemicals	111.5	12.4	2	1	24.6	4	3
41	40	American Hoechst	896	10	1,290	69	Basic chemicals	(10)[h]	—	—	45	na	—	—
42	39	Olin	883	7	1,853	48	Basic chemicals	33.9	1.8	46	40	4.5	47	43
43	42	Conoco	875	10	18,301	5	Petroleum	1026.2	5.6	21	19	22.4	6	5
44	41	Reichhold Chemicals	807	2	885	91	Basic chemicals	16.1	1.8	47	47	7.8	44	46
45	44	National Distillers	744	−4	2,055	36	Alcoholic beverages	110.6	5.4	25	20	9.4	42	37
46	47	Farmland Industries[i]	734	20	4,745	15	Agricultural supplies	182.5[f]	3.8	39	46	34.4	2	10
47	46	Dow Corning	681	12	681	100	Specialty chemicals	73.9	10.8	6	4	19.6	13	6
48	—	Georgia-Pacific	661[d]	22	5,016	13	Lumber and wood products	244	4.9	31	21	11.7	36	23
49	48	Borg-Warner	631	6	2,673	24	Automobile equipment	126.1	4.7	33	28	10.9	41	33
50	49	Nalco Chemical	617	7	617	100	Specialty chemicals	72.3	11.7	5	5	23.6	5	4

a Revised. b Net income as a percentage of net sales. c Net income as a percentage of net worth. d Chemical sales include significant amounts of nonchemical products, such as fabricated plastics, coatings, adhesives, minerals, and the like. e For the year ended Sept. 30. f Company is organized as a farm cooperative; net income represents patronage refunds plus net earnings or net savings. g For the year ended June 30. h Deficit. i For the year ended Aug. 31. na = not available.

SHIPMENTS: Growth in chemical industry sales slowed last year

$ Billions	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
All manufacturing industries	$1798.5	$1692.0	$1496.6	$1330.1	$1185.7	$1039.4	$1017.9	$875.4	$756.5	$671.1	$634.0	6%	11%
Chemicals and allied products	162.4	149.2	126.4	113.9	104.1	89.7	83.7	65.0	57.4	50.9	48.5	9	13
Industrial chemicals[a]	56.0	51.8	42.4	39.1	35.6	29.4	26.6	19.0	16.6	14.9	14.5	8	14
Drugs, soap, and toiletries	45.3	40.1	34.1	30.5	27.8	24.3	22.2	19.3	17.8	15.9	15.1	13	12
Petroleum and coal products	175.5	134.0	103.6	95.7	82.3	69.5	58.9	34.9	28.7	26.9	24.9	31	22
Rubber and plastics products, nec	44.0	44.7	39.9	37.0	31.8	27.2	27.9	24.4	20.9	17.8	16.1	−2	11
Paper and allied products	71.0	66.0	57.7	52.4	48.2	41.7	41.8	32.8	28.3	25.5	24.8	8	11

a Excluding pigments. nec = not elsewhere classified. **Source:** Department of Commerce

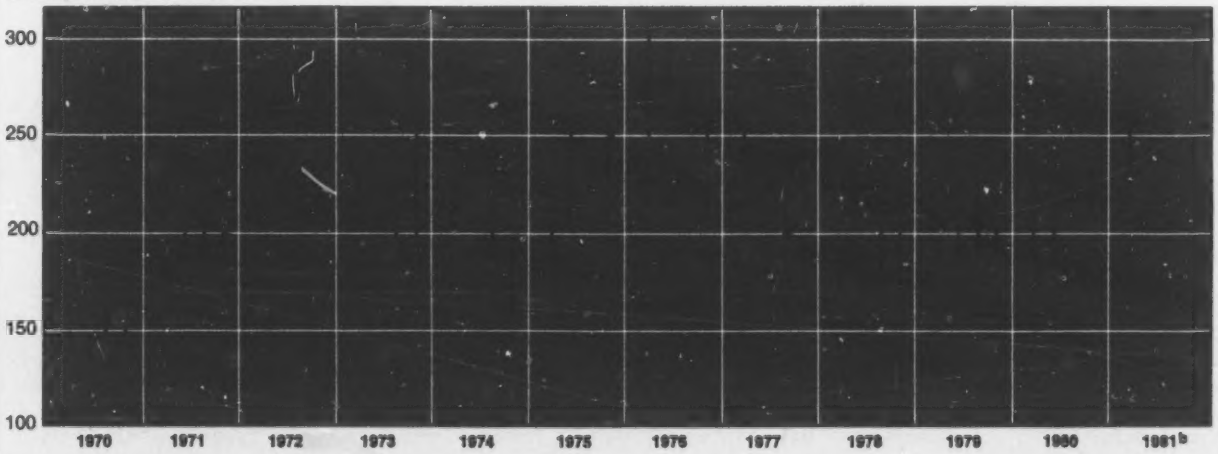
PRICES: Big increases last year for industrial and agricultural chemicals

Producer price indexes,[a] 1967 = 100	Annual average 1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
All commodities	268.6	235.6	209.3	194.2	183.0	174.9	160.1	134.7	119.1	114.0	110.4	14%	9%
Industrial commodities	274.5	236.5	209.4	195.1	182.4	171.5	153.8	125.9	117.9	114.1	110.0	16	10
Chemicals and allied products	260.2	222.3	198.8	192.8	187.2	181.3	146.8	110.0	104.2	104.1	102.2	17	10
Industrial chemicals	323.8	264.0	225.6	223.9	219.3	206.9	151.7	103.4	101.2	102.0	100.9	23	12
Prepared paint	235.4	204.4	192.3	182.4	174.4	166.9	145.7	122.2	118.0	115.6	112.4	15	8
Paint materials	273.8	241.2	212.7	205.9	189.8	177.2	152.3	113.2	104.1	101.5	101.4	14	10
Drugs and pharmaceuticals	174.4	159.4	148.1	140.5	134.0	126.6	112.7	104.3	103.0	102.4	101.2	9	6
Fats and oils, inedible	297.9	376.7	315.8	279.0	249.9	255.2	338.2	228.3	115.8	133.6	132.8	−21	8
Agricultural chemicals and chemical products	256.9	214.4	198.4	187.8	188.4	203.6	137.7	96.6	91.7	92.1	88.5	20	11
Plastic resins and materials	279.4	235.9	199.8	195.7	194.0	180.9	143.8	92.1	88.7	88.7	90.6	18	12
Other chemicals and allied products	224.6	191.8	181.8	175.7	170.7	168.6	147.5	118.1	113.5	112.0	108.6	17	8
Rubber and plastic products	217.3	194.3	174.8	167.6	159.2	150.2	136.2	112.4	109.3	109.1	108.3	12	7

a Formerly called "wholesale price indexes." **Source:** Department of Labor

Chemical stocks have moved up unsteadily since 1978, still well below 1976 peak

Stock price index, 1954 = 100[a]



a C&EN weighted stock price index of Allied Corp., American Cyanamid, Celanese, Dow Chemical, Du Pont, Monsanto, and Union Carbide; weighted according to number of shares outstanding for each company. b First quarter.

INDUSTRY BALANCE SHEET: Chemical companies' cash balances dropped last year

Industrial chemicals and synthetics

Assets	1980 ($ billions)	1979 ($ billions)	Change
Current assets:			
Cash and time deposits	$ 0.88	$ 1.22	−28%
Marketable securities	0.84	0.90	−6
Receivables	12.22	11.03	11
Inventories	10.43	9.47	10
Other current assets	1.76	1.75	0
Total	**26.13**	**24.37**	**7**
Fixed assets:			
Plant, property, and equipment	64.68	58.41	11
Less: accumulated depreciation and depletion	30.82	28.43	8
Net fixed assets	**33.86**	**29.98**	**13**
Other assets: investments, intangibles, etc.	**12.41**	**11.16**	**11**
TOTAL ASSETS	**$72.40**	**$65.52**	**10%**

Source: Federal Trade Commission

Liabilities and stockholders' equity	1980 ($ billions)	1979 ($ billions)	Change
Current liabilities:			
Accounts payable	$5.86	$5.15	14%
Short-term loans	2.45	1.60	53
Income taxes	0.89	1.15	−23
Current portion of long-term debt	0.59	0.62	−5
Other current liabilities	4.87	4.78	2
Total	**14.66**	**13.30**	**10**
Long-term debt	**16.14**	**14.76**	**9**
Deferred taxes and other noncurrent liabilities	**5.15**	**4.86**	**6**
Minority interest	**0.32**	**0.29**	**12**
TOTAL LIABILITIES	**$36.27**	**$33.21**	**9%**
Stockholders' equity:			
Capital stock and other capital	11.30	9.53	19
Retained earnings	25.53	23.54	8
Less: treasury stock	0.71	0.75	−6
TOTAL STOCKHOLDERS' EQUITY	**$36.13**	**$32.32**	**12%**
TOTAL LIABILITIES AND STOCKHOLDERS' EQUITY	**$72.40**	**$65.52**	**10%**

DEBT RATIOS: At the lowest level since mid-1970's for chemical firms

$ Billions	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
INDUSTRIAL CHEMICALS AND SYNTHETICS											
Long-term debt	$16.1	$14.8	$13.6	$12.3	$11.8	$10.2	$7.8	$7.2	$7.6	$7.6	$7.0
Stockholders' equity	$36.1	$32.3	$29.3	$26.3	$25.0	$22.8	$20.5	$18.7	$18.5	$17.5	$16.2
Debt ratio[a]	30.9%	31.4%	31.8%	31.9%	32.0%	30.8%	27.6%	27.8%	29.2%	30.3%	30.1%
CHEMICALS AND ALLIED PRODUCTS											
Long-term debt	$27.5	$24.9	$23.5	$21.1	$19.4	$16.8	$12.8	$10.7	$11.5	$10.7	$10.0
Stockholders' equity	$75.5	$67.4	$60.8	$54.9	$50.8	$45.7	$40.9	$36.7	$36.1	$32.8	$30.6
Debt ratio[a]	26.7%	27.0%	27.9%	27.8%	27.6%	26.9%	23.8%	22.6%	24.2%	24.6%	24.6%
ALL MANUFACTURING											
Long-term debt	$229.6	$204.8	$182.0	$167.3	$153.6	$145.2	$130.1	$112.9	$118.3	$111.5	$102.5
Stockholders' equity	$685.3	$624.0	$560.8	$511.7	$475.3	$435.5	$408.4	$368.0	$353.1	$327.1	$310.8
Debt ratio[a]	25.1%	24.7%	24.5%	24.6%	24.4%	25.0%	24.2%	23.5%	25.1%	25.4%	24.8%

a Long-term debt as a percentage of long-term debt plus stockholders' equity. **Note:** Because of sampling changes, numbers over the entire range of years are not strictly comparable. **Source:** Federal Trade Commission

CASH FLOW: Debt provides more corporate funds, capital outlays soak up a bigger share

$ Millions, % of total	1980		1979		1978		1977		1976	
SOURCES OF FUNDS										
Net income	$ 3,981	33.2%	$ 3,801	36.3%	$3085	33.6%	$2754	30.6%	$2855	32.9%
Depreciation and depletion	3,818	31.8	3,602	34.4	3197	34.8	2833	31.5	2420	27.9
Deferred taxes	679	5.7	427	4.1	353	3.8	357	4.0	374	4.3
Other internal sources	815	6.8	1,093	10.5	930	10.1	1214	13.5	666	7.7
Long-term debt	2,079	17.3	1,210	11.6	1545	16.8	1609	17.9	2220	25.6
Stock	630	5.2	322	3.1	84	0.9	230	2.5	143	1.6
TOTAL	**$12,002**	**100.0%**	**$10,454**	**100.0%**	**$9194**	**100.0%**	**$8997**	**100.0%**	**$8678**	**100.0%**
APPLICATION OF FUNDS										
Dividends	$ 1,603	13.4%	$ 1,474	14.1%	$1317	14.3%	$1184	13.1%	$1055	12.1%
Capital expenditures	7,027	58.5	5,633	53.9	5080	55.3	5488	61.0	5702	65.7
Additions to working capital	1,057	8.8	1,075	10.3	863	9.4	520	5.8	545	6.3
Reduction of long-term debt	1,119	9.3	1,042	10.0	879	9.5	747	8.3	728	8.4
Other applications	1,196	10.0	1,230	11.7	1054	11.5	1058	11.8	648	7.5
TOTAL	**$12,002**	**100.0%**	**$10,454**	**100.0%**	**$9194**	**100.0%**	**$8997**	**100.0%**	**$8678**	**100.0%**

Note: Data are totals for 15 major chemical companies: Allied Corp., American Cyanamid, Celanese, Diamond Shamrock, Dow Chemical, Du Pont, Ethyl Corp., Hercules, Monsanto, Olin, Pennwalt, Rohm & Haas, Stauffer Chemical, Union Carbide, and Williams Cos. **Source:** Company annual reports

FINANCIAL ANALYSIS: Profitability dropped for big chemical firms, but rose for smaller ones

	Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f] as % of sales	CAPITAL SPENDING[f] as % of net plant	R&D spending as % of sales	Sales as % of assets	Net plant as % of gross plant
SALES OVER $1 BILLION												
Air Products[g]	8.1%	4.9%	38.0%	22.7%	25.5%	$ 90	19.7%	25.6%	30.8%	2.1%	81.2%	62.6%
Akzona	0.5	0.4	44.0	na	na	66	200.0	6.1	15.6	2.7	124.5	49.4
Allied Corp.	5.2	3.7	34.7	27.7	25.5	119	32.7	9.7	12.2	1.9	121.6	70.9
American Cyanamid	4.6	4.1	27.5	37.2	27.7	81	48.1	5.7	14.7	4.1	118.4	54.4
Celanese	3.6	2.8	37.8	34.0	18.7	92	44.3	7.6	21.1	2.8	127.1	38.6
Diamond Shamrock	6.4	5.9	39.5	10.5	12.6	248	44.6	12.1	23.8	1.6	112.5	64.4
Dow Chemical	7.6	5.6	43.6	51.7	46.4	187	37.5	11.1	20.9	3.0	90.1	57.4
Du Pont	5.2	4.3	15.8	28.0	23.7	102	57.7	9.3	29.0	3.5	144.4	35.9
Ethyl Corp.	5.1	5.8	23.4	27.8	14.5	118	35.9	9.3	27.3	1.9	146.3	58.0
B. F. Goodrich	2.0	2.2	33.4	21.9	18.8	77	45.5	6.0	19.9	1.6	139.0	51.5
W. R. Grace	4.7	5.6	38.3	25.2	19.2	67	35.9	10.8	30.4	0.7	139.8	65.1
Hercules	4.6	4.3	24.9	25.1	25.9	108	44.6	9.2	26.3	2.2	131.5	46.4
International Minerals[h]	8.1	6.4	35.7	30.2	13.7	170	40.2	14.6	24.7	na	97.3	66.3
Monsanto	3.9	3.0	32.8	32.1	25.8	106	50.1	11.9	25.1	3.1	113.4	51.2
Olin	1.8	1.5	28.4	9.8	10.4	88	72.6	9.3	20.9	1.7	119.5	51.3
Pennwalt	3.6	4.0	31.0	22.1	24.3	93	53.3	4.7	17.7	2.2	143.2	50.7
PPG Industries	6.6	5.3	22.8	20.9	16.0	85	33.5	12.7	25.0	3.2	111.8	51.2
Rohm & Haas	5.4	5.0	24.9	39.5	32.2	131	29.8	5.4	19.0	3.9	139.1	41.2
Stauffer Chemical	7.2	4.7	30.0	13.6	10.2	127	42.4	14.5	23.0	2.6	80.3	63.4
Texasgulf	26.3	13.2	22.8	35.9	43.3	168	19.9	32.3	27.1	na	54.2	78.8
Union Carbide	7.0	5.2	28.0	31.5	29.8	86	29.5	11.3	21.7	1.7	103.5	54.0
Witco Chemical	3.5	5.2	36.1	16.9	15.7	170	34.1	6.2	30.7	1.2	186.3	54.4
Williams Cos.	6.7	5.2	38.1	21.4	na	na	21.6	16.4	24.0	na	87.1	73.8
MEDIAN 1980	**5.1%**	**4.7%**	**32.8%**	**26.5%**	**23.7%**	**$104**	**40.2%**	**9.3%**	**23.8%**	**2.2%**	**119.5%**	**54.4%**
MEDIAN 1979	**6.0%**	**5.1%**	**31.5%**	**25.5%**	**22.3%**	**$96**	**34.8%**	**8.1%**	**21.1%**	**2.0%**	**119.4%**	**52.6%**
SALES FROM $80 MILLION TO $1 BILLION												
Baker Industries	9.8	9.8	30.0	16.0	12.3	251	0	10.6	23.3	na	102.9	71.7
Crompton & Knowles	3.2	4.9	35.9	21.3	21.7	86	40.3	4.0	27.7	1.9	164.7	57.0
Essex Chemical	3.6	5.3	51.8	na	na	na	36.4	4.5	20.4	1.8	168.1	57.7
First Mississippi[h]	8.6	8.2	33.3	16.6	na	na	18.4	15.0	1.7	na	104.6	55.4
Freeport Minerals	22.2	15.6	22.7	na	na	243	21.4	32.6	43.3	na	75.5	63.8
Great Lakes Chemical	14.9	12.7	6.3	18.9	na	na	14.3	16.2	33.2	3.2	107.0	64.9
International Flavors	14.1	13.2	0	69.4	54.8	125	51.6	3.9	14.4	6.4	108.1	60.8
Lawter International	14.7	16.5	0	38.0	36.8	na	58.3	4.5	19.3	1.5	126.9	66.0
Liquid Air	7.2	5.2	30.8	42.4	42.4	100	53.1	14.8	22.3	1.0	91.8	63.1
Loctite[h]	13.0	15.5	12.3	45.4	53.2	77	23.2	7.0	40.1	2.5	110.8	72.4
Lubrizol	12.1	14.9	4.8	61.4	46.4	222	32.1	10.0	37.0	3.0	141.7	81.9
Mallinckrodt	8.1	9.1	13.2	na	na	92	32.8	7.5	21.9	3.5	123.8	68.9
Nalco Chemical	11.7	14.5	3.3	24.0	22.2	140	44.1	5.7	25.3	4.5	148.2	50.2
Petrolite[i]	9.8	11.0	10.0	24.6	21.5	na	28.5	6.5	25.2	2.5	144.6	54.1
Reichhold Chemicals	1.8	3.1	32.0	18.0	19.6	159	44.7	2.6	12.6	0.7	206.7	61.0
Stepan Chemical	3.4	3.6	34.2	na	na	192	33.3	5.8	14.3	3.2	114.4	64.1
Thiokol	4.6	6.1	3.3	19.0	12.0	64	35.1	5.6	22.2	1.7	153.8	60.4
MEDIAN 1980	**9.8%**	**9.8%**	**13.2%**	**22.7%**	**36.8%**	**$148**	**33.3%**	**5.8%**	**22.3%**	**2.5%**	**123.8%**	**61.9%**
MEDIAN 1979	**8.3%**	**7.2%**	**19.5%**	**21.5%**	**21.2%**	**$120**	**34.3%**	**5.6%**	**20.1%**	**2.7%**	**130.4%**	**60.2%**

a Net income as a percentage of sales. b Net income as percentage of current assets plus gross plant. c Consolidated sales only. d Foreign identifiable assets as percentage of total assets. e Thousands of dollars. f Actual spending on construction of new facilities and purchase of new equipment and land in consolidated businesses. g For fiscal year ended Sept. 30, 1979. h For fiscal year ended June 30, 1979. i For fiscal year ended Oct. 31, 1979. na = not available. **Note:** Net income excludes extraordinary or nonrecurring profits and earnings from discontinued operations, where possible.

INDUSTRY CAPITAL SPENDING: Chemical plant, equipment outlays have doubled since 1974

$ Billions	1981[a]	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971
Chemicals	$13.11	$12.60	$10.78	$8.46	$8.14	$8.12	$7.63	$6.48	$4.24	$3.38	$3.26
Iron and steel	3.27	3.29	3.09	2.52	2.79	3.04	3.03	1.94	1.25	1.06	1.27
Nonferrous metals	3.59	3.11	2.39	2.11	1.88	1.97	2.18	2.04	1.30	0.97	1.02
Paper	6.73	6.80	5.55	3.99	3.59	3.11	2.98	2.90	2.00	1.45	1.29
Petroleum	25.17	20.69	16.21	13.95	12.70	10.76	9.59	7.31	4.68	4.80	5.21
Rubber	2.30	1.73	2.17	2.10	1.66	1.32	1.15	1.56	1.55	1.03	0.78
Stone, clay, glass	3.90	3.82	3.94	3.10	2.23	1.88	1.67	1.64	1.58	1.33	0.73
All manufacturing	129.85	115.81	98.68	79.72	69.22	59.95	54.92	53.21	42.37	35.42	33.60

a Estimate. **Source:** Department of Commerce

Backlogs of unspent capital funds have ballooned in the chemical industry

$ Billions	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
Chemicals	$9.8	$8.5	$7.2	$7.4	$7.1	$6.9	$6.6	$4.9	$2.9	$2.3	$2.5
Iron and steel	3.9	4.5	4.0	3.6	4.7	5.4	5.8	2.4	1.9	1.8	2.2
Nonferrous metals	3.7	2.9	2.7	2.9	2.4	2.2	2.7	2.2	1.1	0.7	0.8
Paper	4.0	4.2	3.2	2.6	2.0	2.7	2.9	1.7	1.1	0.8	1.0
Petroleum, coal	26.7	16.1	14.6	15.0	12.2	14.1	12.8	7.1	4.3	3.8	4.2
Rubber	1.0	0.9	0.9	0.8	0.7	0.6	0.7	0.9	0.8	0.5	0.5
Stone, clay, glass	2.0	2.3	2.4	2.0	1.5	1.4	1.7	1.5	0.8	0.5	0.4
All manufacturing	91.9	76.7	63.4	56.5	47.5	46.4	49.8	37.1	23.3	18.9	20.9

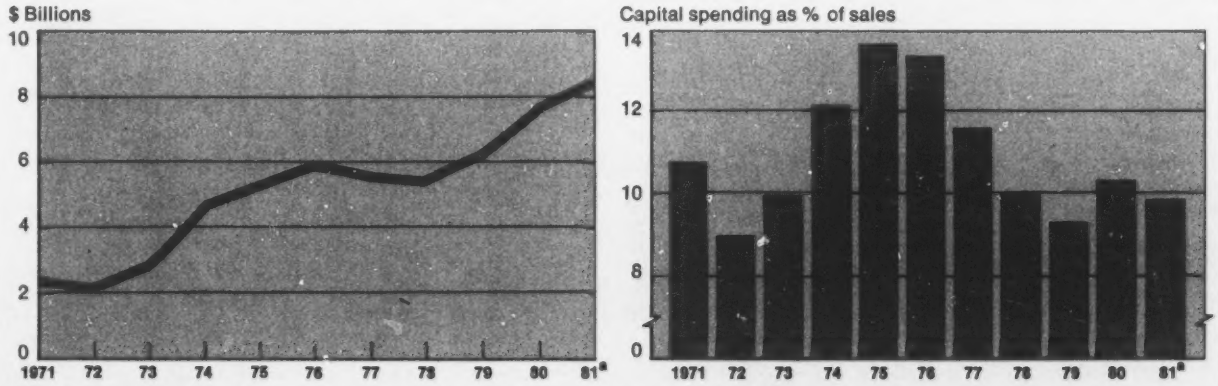
Note: Figures are for fourth quarter each year. **Source:** Conference Board

Chemical capital spending continues to increase outside U.S.

$ Billions[a]	1981[b]	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
Chemicals and allied products	$ 3.9	$ 3.6	$ 3.4	$ 2.5	$ 2.4	$ 2.7	$ 2.5	$ 2.1	$1.4	$1.2	$1.2	$1.2
Metals, primary and fabricated	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.8	0.6	0.6	0.7
Paper and allied products	1.7	1.5	0.9	0.8	0.7	0.6	0.7	0.9	0.6	0.5	0.6	0.4
Rubber products	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.2
All manufacturing	24.8	23.4	18.8	14.6	12.7	10.9	11.3	11.6	9.2	7.2	7.0	6.5
Petroleum	16.7	14.8	11.6	10.0	9.3	7.9	8.9	7.8	6.4	5.2	5.0	4.0

a By majority-owned affiliates of U.S. companies. b Planned. **Source:** Department of Commerce

Chemical capital spending is rising more slowly this year, won't keep pace with sales



a Planned. **Sources:** Worldwide data for 17 large U.S. basic chemical companies, C&EN estimates

U.S. chemical companies are holding down their increases in spending for new plant and equipment even more in 1981 than they did in recessionary 1980. The result will be the fourth year in a row of relatively low spending compared to industry sales. In other words, the industry's mild capital spending climate will continue, in marked contrast to the frenetic pace during and after the previous recession in 1975.

The latest revision to C&EN's annual worldwide capital spending survey of 17 large U.S. basic chemical companies shows plans for a 9% increase to $8.48 billion for capital spending in 1981 from $7.77 billion in 1980. The final 1980 total is up 23% from 1979.

The government's capital spending surveys show a similar downward shift in spending increases planned for U.S. projects in 1981. For chemicals and allied products, the Commerce Department shows planned increases of just 4% this year to $13.11 billion. Last year, spending climbed 16%, according to Commerce figures, to $12.60 billion.

Since inflation continues quite strong this year, the planned capital spending gains in the chemical industry represent hardly any real gain. Compared to the industry's expected sales increase this year, capital spending will continue to be very modest. C&EN estimates that capital spending will be about 9.8% of industry sales in 1981 after 10.3% in 1980 and 9.3% in 1979. Capital spending has fallen below 9% of the chemical industry's sales only once in the past decade.

By comparison, at this point in the previous business cycle just after the 1975 recession, chemical capital spending peaked at 13.7% of industry sales and stayed high at 13.4% in 1976. The industry paid for this exuberance with two poor profit years in 1976 and 1977 while product demand caught up with companies' swollen plant capacity.

Another measure of the chemical industry's current restraint is the pileup of project backlogs. Since the industry is quite capable of funding more plant and equipment spending than it has, companies' appropriations for future projects have stayed fairly high. But actual spending has hardly matched the appropriations pace. The result, according to regular surveys by the Conference Board, was a 15% jump in unspent chemical industry backlogs to $9.8 billion in 1980 after an 18% increase in 1979. Behind the backlog figures, the Conference Board reports appropriations gains in the chemical industry of 38% in 1979 and 14% in 1980. Meanwhile, actual spending was up 19% in each year.

CHEMICAL CAPITAL SPENDING: Leading chemical firms cut back on hikes in 1981 from 1980

$ Millions	1981[a]	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971
Air Products	$ 400	$ 364	$ 246	$ 200	$ 143	$ 162	$ 151	$ 110	$ 67	$ 42	$ 79
Akzona	60	64	54	42	35	38	51	57	42	43	73
Allied Corp.	600	533	409	502	465	352	314	306	194	128	132
American Cyanamid	205	196	235	251	235	232	204	139	83	72	111
Celanese	350	253	245	248	243	223	208	220	159	128	169
Diamond Shamrock	500	381	257	319	390	334	183	201	103	61	56
Dow Chemical	1400	1184	1268	1075	1163	1200	935	890	415	359	365
Du Pont	1300	1279	864	714	704	876	1036	1008	781	561	474
Ethyl Corp.	165	156	123	96	88	88	69	75	35	32	24
W. R. Grace	700	657	511	309	279	234	309	303	174	135	98
Hercules	220	229	186	116	127	150	151	217	144	80	53
Monsanto	800	781	566	480	607	647	528	313	205	168	205
Olin	175	172	161	163	208	166	99	67	78	76	55
Pennwalt	70	56	67	62	46	40	32	43	25	22	23
Rohm & Haas	150	93	68	66	79	110	106	106	73	62	85
Stauffer Chemical	230	246	239	201	193	199	199	83	45	35	52
Union Carbide	1150	1129	831	688	805	965	862	517	289	244	335
TOTAL	$8475	$7773	$6330	$5532	$5810	$6016	$5437	$4655	$2912	$2248	$2389
ANNUAL CHANGE	9%	23%	14%	−5%	−3%	11%	17%	60%	30%	−6%	−4%

a Planned. **Note:** Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. **Sources:** Company data, C&EN estimates

In contrast to the modest capital spending pace in the U.S. chemical industry, research and development projects are pulling down strong increases in support. This part of the industry's future-oriented activity is in robust health and promises a continued good job market for scientists and engineers.

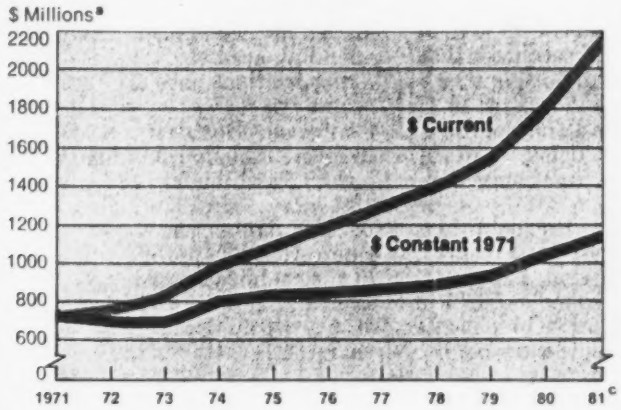
C&EN's latest survey of worldwide R&D spending plans by 15 large U.S. basic chemical companies shows a planned gain of 18% to $2.19 billion in 1981 from $1.85 billion in 1980. The 1980 final figure is up 17% from 1979, the largest annual increase since 1974.

These increases are running comfortably ahead of the industry R&D inflation rate, estimated by Battelle Columbus Laboratories at 9.1% this year after 6.3% in 1980. The considerable leeway for real-dollar gains in R&D support implies increased project and staff levels, which historically have followed the pace of real-dollar R&D support.

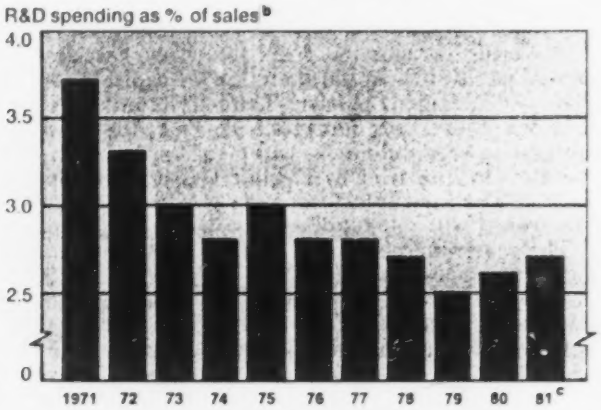
This year also could bring the second straight annual increase in R&D support relative to industry sales after a falling trend over the past decade. C&EN estimates that the 15 companies in its survey will push R&D spending to about 2.7% of sales this year from 2.6% in 1980 and 2.5% in 1979.

A glance at the individual company budgets in C&EN's survey shows some sizable increases, especially at the largest companies. Number one as always in R&D support is Du Pont with an 18% planned spending increase this year to $570 million, the first U.S. chemical R&D budget to surpass $500 million.

R&D funding by chemical companies outpaces inflation this year ...



... and also may increase relative to company sales, although not by much



a R&D spending by basic chemical companies. b By basic chemical companies. c Estimate. **Sources:** Worldwide data for 15 U.S. basic chemical companies, Battelle Columbus Laboratories, C&EN estimates

CHEMICAL R&D SPENDING: Large increases continue at many companies in 1981

$ Millions	1981[a]	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971
Air Products	$ 32	$ 30	$ 24	$ 23	$ 24	$ 19	$ 16	$ 11	$ 8	$ 7	$ 7
Akzona	33	28	25	23	20	18	17	16	13	11	10
Allied Corp.	145	105	70	56	51	40	35	31	29	29	31
American Cyanamid	160	142	124	108	96	83	73	64	52	44	43
Celanese	105[b]	94	92	83	77	70	64	58	49	52	51
Diamond Shamrock	60	50	42	36	29	24	20	14	12	12	11
Dow Chemical	400	314	269	232	203	188	167	149	118	105	95
Du Pont	570	485	415	377	367	353	336	344	286	265	259
W. R. Grace	54	45	42	37	32	28	30	32	28	22	21
Hercules	57	53	47	40	37	35	30	30	25	24	22
Monsanto[c]	230	204	161	136	132	114	116	87	82	92	87
Pennwalt[d]	28	26	24	23	21	19	16	14	13	18	17
Rohm & Haas	80	67	54	49	45	43	45	39	32	25	29
Stauffer Chemical	52	44	37	34	33	29	24	20	17	14	14
Union Carbide	188	166	161	156	156	143	120	94	77	70	78
TOTAL	$2194	$1853	$1587	$1409	$1323	$1206	$1109	$1003	$841	$790	$775
ANNUAL CHANGE	18%	17%	13%	7%	10%	9%	11%	19%	6%	2%	−3%

a Planned. b C&EN estimate. c R&D definition narrowed after 1972. d For chemicals only before 1972. **Sources:** Company data, C&EN estimates

Caught between rising operating costs and stagnating or depressed demand for many of their leading products, chemical producers clearly found profits harder to come by last year. But by and large, they managed to maintain their profitability relatively well, despite the business recession.

Industry totals or averages tell only part of the story. The overall chemicals and allied products industry is comprised of companies of widely diverse characteristics that produce a greatly varying array of products. And as the data on this and the following four pages—which present financial results covering the past four years for 48 leading chemical and pharmaceutical firms—indicate, considerable diversity exists among the companies within the industry.

Although for the majority of chemical companies, profit margins and return on investment declined, for example, nearly a third were able to improve their record last year. Thus it was not a bad year to have a stake in the oil business, industrial gases, or fertilizers. Witness the results rung up by firms like Allied Corp., Air Products, Big Three Industries, First Mississippi, W. R. Grace, and Williams Cos. (Although for the fertilizer makers, last year's improvement largely reflects a comeback from depressed conditions of previous years.) But it was not a particularly good year to be involved heavily with plastics or synthetic fibers, as the figures for companies such as Akzona, Celanese, Du Pont, and Monsanto suggest.

Explanation of table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, but these items are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents and trademarks, and the like.

Current ratio. The ratio of current assets (cash, marketable securities, receivables, and inventories but excluding prepaid expenses) to total current liabilities.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Net worth. Equity at year's end of preferred and common stock holders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). **Per cent of sales:** net income divided by net sales. **Per cent of net worth:** net income divided by tangible net worth. **Dollars per share:** net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits but no adjustment has been made for earlier years as a result of stock dividends nor for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the calendar year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share of common stock.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
	Money figures in thousands of dollars unless otherwise indicated													
CHEMICALS														
Air Products & Chemicals														
1980[a]	$1,420,759	$115,502	$1,744,392	1.3	$1,182,567	$364,013	$658,596	8.1%	17.5%	$4.07	$1.80	1.8%	$54¼–32¼	10.6
1979[a]	1,229,594	97,540	1,415,024	1.3	945,013	246,050	563,702	7.9	17.3	3.45	0.65	2.1	37¼–23¾	8.8
1978[a]	1,039,052	76,184	1,180,754	1.2	801,809	199,847	477,557	7.3	16.0	2.70	0.50	1.8	31⅞–22½	10.1
1977[a]	947,239	67,707	1,022,546	1.5	691,904	142,616	416,190	7.1	16.3	2.40	0.25[b]	0.9	35⅞–21	11.8
Akzona														
1980	$1,054,015	$4,877	$846,708	2.1	$412,009	$84,313	$319,139	0.5%	1.5%	$0.40	$0.80	6.3%	$17½–7¾	31.6
1979	1,012,398	25,647	818,125	2.2	402,178	54,486	323,875	2.5	7.9	2.10	0.80	5.6	17⅛–11¼	6.8
1978	868,711	20,832	704,095	2.5	374,065	42,404	307,790	2.4	6.8	1.69	0.80	6.0	15¼–11¼	7.8
1977	808,847	7,523	674,937	2.6	374,315	35,191	300,287	0.9	2.5	0.60	1.10	7.2	19⅛–11¼	25.3
Allied Corp.														
1980	$5,519,000	$303,000[e]	$4,475,000	1.3	$2,384,000	$533,000	$1,861,000	5.5%	16.3%	$8.59[e]	$2.15	4.3%	$61¾–39	5.9
1979	4,332,391	201,080[d]	4,159,798	1.1	2,168,816	408,668	1,377,701	4.6	14.6	6.84[d]	2.00	5.1	49½–28½	5.7
1978	3,267,956	124,557[e]	3,182,335	1.4	2,041,409	502,040	1,226,710	3.8	10.2	4.40[e]	2.00	5.5	44¾–27⅝	8.2
1977	2,922,751	138,378[f]	2,825,965	1.7	1,809,369	464,638	1,151,112	4.7	12.0	4.93[f]	1.85	4.1	51⅜–38¾	9.1
American Cyanamid Co.														
1980	$3,453,934	$159,195	$2,900,289	1.8	$1,328,691	$195,819	$1,419,073	4.6%	11.2%	$3.32	$1.60	5.5%	$ 38–20⅝	8.8
1979	3,186,998	168,495	2,810,725	1.6	1,303,308	235,416	1,331,130	5.3	12.7	3.52	1.60	5.3	36⅛–23¾	8.5
1978	2,780,170	155,943	2,510,038	1.8	1,212,807	251,034	1,238,396	5.6	12.6	3.26	1.50	5.4	32⅞–22⅝	8.5
1977	2,412,311	139,400	2,205,363	2.0	1,081,908	235,451	1,152,003	5.8	12.1	2.92	1.50	5.7	29¾–23	9.0

a Fiscal year ends Sept. 30. b Plus 2% stock dividend. c Excludes nonrecurring net loss from estimated plant shutdown and disposal costs of $14 million ($0.44 per share). d From continuing operations; excludes net losses from discontinued businesses of $164.8 million ($5.75 per share) and nonrecurring net loss of $25.4 million ($0.89 per share). e Excludes nonrecurring net loss from sales of plants of $4.3 million ($0.15 per share). f Excludes extraordinary charge representing costs related to Kepone problem of $3.1 million ($0.11 per share), but includes net gains on disposition of operating assets and real estate, less provision for write-off of notes held or guaranteed, of $16.0 million.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
					Money figures in thousands of dollars unless otherwise indicated									
Big Three Industries														
1980	$659,121	$86,604	$815,048	2.2	$583,772	$142,542	$472,607	13.1%	18.3%	$2.05	$0.47[a]	1.7%	$36 1/8-18 7/8	13.4
1979	509,449	62,859	700,052	2.3	488,921	79,710	404,137	12.3	15.6	1.56	0.42	2.2	22 1/4-15 3/4	12.2
1978	428,934	56,718	604,437	2.2	449,707	93,374	357,478	13.2	15.9	1.41	0.34	2.0	20 1/4-14 1/2	12.3
1977	341,171	49,227	515,830	2.3	391,086	124,494	313,845	14.4	15.7	1.23	0.20[b]	1.3	17 3/4-13 5/8	12.8
Cabot Corp.														
1980[c]	$1,403,743	$94,024[d]	$1,138,683	2.0	$456,507	$117,705	$497,546	6.7%	18.9%	$3.00[d]	$0.67	2.6%	$36 3/8-14 3/4	8.5
1979[c]	1,122,391	70,445	918,431	2.0	401,638	68,266	358,031	6.3	19.7	2.28	0.47	3.5	16 5/8-10 1/8	5.9
1978[c]	713,136	46,580	752,089	2.5	353,020	111,902	303,542	6.5	15.3	1.53	0.35	3.5	12 7/8-7	6.5
1977[c]	574,836	39,901	575,322	2.6	273,104	50,258	280,932	6.9	14.2	1.26	0.25	3.5	8 1/4-6 1/8	5.7
Celanese Corp.														
1980	$3,348,000	$122,000	$2,633,000	2.0	$1,197,000	$253,000	$1,101,000	3.6%	11.1%	$8.20	$3.50	6.8%	$62 5/8-39 7/8	6.2
1979	3,146,000	141,000	2,374,000	1.8	1,150,000	245,000	1,033,000	4.5	13.6	9.52	3.10	7.0	48 3/4-39 3/8	4.6
1978	2,609,000	112,000[e]	2,148,000	2.0	1,148,000	248,000	936,000	4.3	12.0	7.61[e]	2.85	6.9	47 1/8-35 5/8	5.4
1977	2,320,000	70,000	1,998,000	2.0	1,119,000	243,000	816,000	3.0	8.6	4.70	2.80	6.0	53-40	9.9
Crompton & Knowles Corp.														
1980	$241,776	$7,666	$135,619	2.5	$34,731	$9,623	$58,935	3.2%	13.0%	$3.33	$1.20	5.8%	$24 7/8-16 3/8	6.2
1979	239,638	7,075	131,433	2.2	28,822	7,895	55,212	3.0	12.8	3.05	1.04	6.6	18 3/8-13	5.1
1978	217,412	6,137	127,177	2.3	25,110	4,484	49,699	2.8	12.3	2.65	0.96	6.1	19-12 5/8	6.0
1977	192,729	5,408	107,175	2.7	24,105	2,976	45,938	2.8	11.8	2.35	0.90	6.0	17 1/4-12 3/4	6.4
Diamond Shamrock Corp.														
1980	$3,143,040	$201,214	$2,707,284	2.1	$1,600,250	$381,036	$1,155,950	6.4%	17.4%	$3.66	$1.62	5.2%	$38 7/8-23 1/8	8.5
1979	2,356,858	178,123	2,329,892	1.9	1,382,931	256,564	931,267	7.6	19.1	3.37	1.51	6.0	31 1/2-19	7.5
1978	1,677,602	131,063	1,969,509	1.9	1,294,970	286,843	790,555	7.8	16.6	3.26	1.42	5.8	29 3/4-19	7.5
1977	1,530,382	162,123	1,718,768	2.0	1,140,768	367,512	701,179	10.6	23.1	4.28	1.175	3.6	38 5/8-26 3/8	7.6
Dow Chemical Co.														
1980	$10,626,000	$753,000[f]	$11,429,000	1.5	$5,672,000	$1,184,000	$4,331,000	7.1%	17.4%	$4.14[f]	$1.60	4.7%	$39 1/4-28 1/4	8.2
1979	9,255,387	734,000[g]	10,144,745	1.4	5,236,404	1,267,719	3,789,746	7.9	19.4	4.05[g]	1.45	4.9	34 7/8-24 3/8	7.3
1978	6,887,623	575,224	8,705,081	1.6	4,762,129	1,075,173	3,310,655	8.4	17.4	3.16	1.25	4.7	30 7/8-22	8.4
1977	6,234,255	555,703	7,591,752	1.5	4,199,539	1,163,016	3,033,636	8.9	18.3	3.01	1.10	3.2	43 3/4-25 1/4	11.5
E. I. du Pont de Nemours & Co.														
1980	$13,652,000	$716,000	$9,560,000	2.3	$4,414,000	$1,279,000	$5,690,000	5.2%	12.6%	$4.83	$2.75	6.8%	$49 1/2-31 1/8	8.3
1979	12,571,800	938,900	8,918,700	2.5	3,942,400	864,000	5,290,600	7.5	17.7	6.42	2.75	6.5	48 1/4-37	6.6
1978	10,584,200	787,000	8,047,700	2.3	3,839,000	714,200	4,737,800	7.4	16.6	5.39	2.42	6.1	46 1/8-32 1/2	7.3
1977	9,434,800	545,100	7,379,500	2.5	3,886,200	703,600	4,265,900	5.8	12.5	3.69	1.92	4.8	45-35 1/8	10.9
Ethyl Corp.														
1980	$1,740,627	$82,397[h]	$1,138,233	2.4	$602,029	$156,388	$631,831	4.7%	13.0%	$4.11[h]	$1.50	5.1%	$36 1/2-22 1/4	7.1
1979	1,656,977	97,515	1,070,968	2.8	512,981	122,878	536,671	5.9	18.2	4.94	1.35	5.3	30-21	5.2
1978	1,422,451	82,698	1,001,584	2.9	446,346	95,803	514,693	5.8	16.1	4.24	1.10	5.1	24 7/8-18 1/2	5.1
1977	1,282,087	78,024	911,072	3.5	402,335	87,649	463,070	6.1	16.8	4.29	0.875	4.2	22 7/8-18 3/8	4.8
Ferro Corp.														
1980	$695,580	$29,019	$430,472	2.0	$134,563	$31,505	$220,597	4.2%	13.2%	$3.77	$1.20	5.8%	$24 1/4-17	5.5
1979	591,930	30,912	387,703	1.8	115,831	33,132	200,625	5.2	15.4	4.07	1.14	4.7	29 3/8-19	5.9
1978	494,414	27,657	310,612	2.0	86,805	19,385	175,618	5.6	15.7	3.67	1.05	4.0	35-17 1/8	7.1
1977	420,042	20,903	254,254	2.4	71,902	19,693	157,975	5.0	13.2	2.78	0.90	4.5	22 5/8-17 3/8	7.2
First Mississippi Corp.														
1980[i]	$242,690	$21,154	$236,579	2.1	$83,525	$37,202	$113,672	8.7%	18.6%	$0.98	$0.18	0.9%	$30 3/4-7 1/2	19.5
1979[i]	178,400	4,661	200,370	2.8	63,942	17,046	95,073	2.6	4.9	0.22	0.16	2.0	11 3/4-4	35.8
1978[i]	155,525	4,170	205,837	2.9	72,190	12,558	93,528	2.7	4.5	0.20	0.16	3.2	6 5/8-3 1/4	25.0
1977[i]	161,448	14,435[j]	210,679	2.8	76,476	25,112	91,986	8.9	15.7	0.69[j]	0.14	2.8	6 7/8-3 1/2	7.4
W. R. Grace & Co.														
1980	$6,101,300	$283,800[k]	$4,281,500	1.5	$2,162,700	$657,400	$1,713,100	4.7%	16.6%	$6.08[k]	$2.175	4.5%	$63 1/2-32 5/8	7.9
1979	5,266,629	222,580[l]	3,680,847	1.6	1,629,361	477,688	1,524,276	4.2	14.6	5.02[l]	1.975	5.9	41 1/4-25 5/8	6.7
1978	4,309,588	170,403[m]	3,201,126	1.9	1,317,159	275,308	1,333,772	4.0	12.8	4.23[m]	1.85	6.6	32 3/8-23 3/4	6.6
1977	3,976,233	140,475[n]	2,870,719	1.8	1,216,950	263,633	1,156,899	3.5	12.1	3.71[n]	1.775	6.2	31 5/8-25 7/8	7.7
Hercules														
1980	$2,485,226	$114,000	$1,889,679	2.0	$872,656	$229,163	$1,009,746	4.6%	11.3%	$2.60	$1.20	6.0%	$ 25-15 1/8	7.7
1979	2,345,425	144,500[o]	1,761,177	1.9	772,889	185,998	945,422	6.2	15.3	3.27[o]	1.075	5.5	22 3/4-16 1/8	5.9
1978	1,946,477	103,264[p]	1,590,306	1.9	714,286	115,807	812,159	5.3	12.7	2.36[p]	1.00	6.5	18 5/8-12 1/4	6.5
1977	1,697,787	57,930[q]	1,469,276	2.2	721,292	127,484	749,303	3.4	7.7	1.36[q]	1.00	4.6	28 1/2-14 3/4	15.9

a Plus 5% stock dividend. b Plus 2% stock dividend. c Fiscal year ends Sept. 30. d From continuing operations; excludes net income from discontinued operations of $12.3 million ($0.39 per share) and gain on sale of machinery division of $46.4 million ($1.49 per share). e Excludes cumulative effects of change in accounting for investment tax credits of $43 million ($3.01 per share). f Excludes net gain on sale of Wanda Petroleum Co. of $52 million ($0.28 per share). g Excludes net gain on sale of Canadian oil and gas properties of $50 million ($0.28 per share). h Excludes net capital gain on sale of property of $7.3 million ($0.38 per share). i Fiscal year ends June 30. j Includes gains on sale of oil and gas leases, from cancellation of raw material purchase contract, and on settlement of litigation of $5.1 million. k Includes net losses on disposal of businesses of $10.3 million. l Includes net gains on disposal of businesses of $5.2 million. m Includes gains on disposal of businesses of $8.0 million. n Includes net losses on disposal of businesses of $17.2 million. o Includes net gain on sale of pigments and methanol assets of $28.0 million ($0.62 per share). p Includes net loss from write-down of facilities of $4.9 million ($0.11 per share). q Includes net loss from write-down of facilities of $6.2 million ($0.26 per share).

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
					Money figures in thousands of dollars unless otherwise indicated									
International Flavors & Fragrances														
1980	$448,309	$63,232	$414,859	3.8	$121,228	$17,461	$315,485	14.1%	20.0%	$1.73	$0.86	3.9%	$27½–16⅝	12.8
1979	409,299	61,472	387,807	3.6	114,255	15,180	285,425	15.0	21.5	1.68	0.74	3.4	25⅝–18¼	13.1
1978	365,881	56,199	345,073	3.4	109,092	20,014	252,706	15.4	22.2	1.53	0.59	2.5	27⅝–19⅝	15.4
1977	314,307	45,705	306,045	3.2	98,567	16,640	219,230	14.5	20.8	1.25	0.46	2.2	23⅝–18¼	16.8
International Minerals & Chemical Corp.														
1980[a]	$1,789,600	$145,900	$1,848,600	2.0	$1,062,900	$262,100	$881,300	8.2%	16.6%	$5.38	$2.16	4.5%	$66½–30	9.0
1979[a]	1,474,700	120,800	1,537,600	1.7	936,600	173,500	790,200	8.2	15.3	4.48	1.87	5.8	41–23½	7.2
1978[a]	1,364,400	120,100	1,461,900	1.9	879,400	193,600	721,000	8.8	16.7	4.41	1.73	6.7	29–22⅝	5.9
1977[a]	1,280,200	108,200	1,368,600	2.0	778,600	174,800	649,300	8.5	16.7	4.06	1.63	6.2	29⅜–23½	6.5
Liquid Air Corp. of North America														
1980	$408,249	$27,448[b]	$425,502	1.6	$270,778	$60,469	$202,832	6.7%	13.5%	$2.57[b]	$1.40	5.2%	$34½–19¾	10.6
1979	369,109	24,698	399,354	1.7	259,006	50,714	191,641	6.7	12.9	2.49	1.40	5.3	28¾–23¾	10.5
1978	304,266	18,346	299,419	1.8	180,327	37,092	121,097	6.0	15.1	2.48	1.40	5.2	30½–23½	10.9
1977	284,495	19,896	275,004	1.8	160,321	31,914	113,751	7.0	17.5	2.75	1.40	5.0	32¾–23½	10.2
Lubrizol Corp.														
1980	$902,312	$111,511	$651,137	2.5	$248,664	$92,140	$452,787	12.4%	24.6%	$5.74	$1.80	2.7%	$83⅜–49⅝	11.6
1979	724,734	90,775	519,942	2.5	180,405	50,807	374,751	12.5	24.2	4.66	1.60	3.2	59⅞–41	10.8
1978	586,477	77,365	441,735	2.8	150,018	44,373	323,036	13.2	23.9	3.95	1.405	3.4	48¼–33⅜	10.3
1977	507,121	58,069	360,467	3.2	121,369	22,982	271,783	11.5	21.4	2.96	1.25	3.8	37⅜–27¾	11.0
Mallinckrodt Inc.														
1980	$441,795	$36,002	$342,803	3.6	$151,284	$33,135	$239,782	8.1%	15.0%	$3.82	$1.25	3.1%	$55½–25¼	10.6
1979	392,470	31,932[c]	317,798	3.4	130,416	19,640	213,617	8.1	14.9	3.40[c]	1.05	3.5	33¼–26½	8.8
1978	365,722	28,841	271,030	3.8	125,585	17,062	180,778	7.9	16.0	3.07	0.90	2.7	41¾–26	11.0
1977	313,204	27,163	243,051	4.1	113,015	25,195	158,387	8.7	17.1	2.89	0.75	2.1	40¼–29¾	12.1
Monsanto Co.														
1980	$6,573,600	$148,800[d]	$5,796,400	2.1	$3,109,100	$780,500	$2,808,200	2.3%	5.3%	$4.10[d]	$3.55	6.3%	$70¼–42¼	13.7
1979	6,192,600	331,000[e]	5,539,100	2.2	2,817,800	565,900	2,781,800	5.3	11.9	9.11[e]	3.35	6.3	62–45	5.9
1978	5,018,700	302,600[f]	5,035,700	2.5	2,604,800	479,900	2,579,400	6.0	11.7	8.29[f]	3.175	6.1	60¼–44⅛	6.3
1977	4,594,500	275,600	4,350,100	2.6	2,408,700	607,100	2,400,900	5.9	11.5	7.46	3.025	4.3	88⅞–52	9.4
Nalco Chemical Co.														
1980	$616,709	$72,261	$416,233	2.7	$138,137	$34,923	$306,550	11.7%	23.6%	$3.61	$1.60	3.9%	$53¼–27⅞	11.2
1979	578,908	63,277	368,074	2.5	126,774	39,018	261,966	10.9	24.2	3.18	1.36	4.4	35⅝–26¼	9.7
1978	476,208	53,652[g]	309,666	2.5	105,197	34,278	221,814	11.3	24.2	2.71[g]	1.24	4.3	32¾–24⅜	10.5
1977	445,602	50,113	285,005	2.5	99,890	35,324	208,286	11.2	24.1	2.51	1.065	3.6	34⅝–24¾	11.8
Olin Corp.														
1980	$1,852,853	$73,931[h]	$1,550,128	1.7	$822,412	$172,016	$750,120	4.0%	9.9%	$3.08	$1.025	5.8%	$23⅛–12½	5.8
1979	1,778,102	71,150	1,461,073	1.7	764,108	161,151	739,992	4.0	9.6	2.97	0.97	4.7	25–16⅛	6.9
1978	1,560,075	62,769	1,393,064	1.7	742,158	162,519	691,563	4.0	9.1	2.62	0.88	4.5	25¾–13⅜	7.5
1977	1,472,500	78,116	1,276,097	2.0	666,580	208,140	653,066	5.3	12.0	3.24	0.815	4.2	22⅛–16⅝	6.0
Pennwalt Corp.														
1980	$1,188,702	$43,291	$810,761	2.0	$314,315	$55,546	$373,363	3.6%	11.6%	$4.20	$2.20	7.4%	$34⅜–25⅜	7.1
1979	1,079,363	49,997	775,355	2.1	298,420	67,486	346,140	4.6	14.4	5.01	2.20	6.1	35⅞–30½	6.6
1978	921,369	44,973	672,343	2.1	270,374	61,938	317,073	4.9	14.2	4.54	2.00	5.4	42½–31½	8.1
1977	834,895	41,733	608,654	2.5	241,432	45,957	288,782	5.0	14.5	4.23	1.75	4.9	39¼–31⅝	8.4
Reichhold Chemicals														
1980	$885,059	$16,114	$424,760	2.1	$179,550	$22,656	$203,941	1.8%	7.9%	$1.90	$0.61	5.0%	$15–9⅝	6.5
1979	874,854	12,230	425,478	2.0	179,960	26,114	194,619	1.4	6.3	1.34	0.74	5.4	16–11¼	10.2
1978	753,885	12,038[i]	393,433	2.0	24,287	190,493	190,493	1.6	6.3	1.32[i]	0.74	5.4	16½–11	10.4
1977	673,942	13,711	383,055	2.0	173,136	26,222	186,499	2.0	7.4	1.70	0.74	4.5	20–13¼	9.8
Rohm & Haas Co.														
1980	$1,725,304	$93,744	$1,240,456	2.6	$488,185	$93,013	$703,124	5.4%	13.3%	$7.26	$2.16	4.9%	$55¼–32¾	6.1
1979	1,590,484	95,495[j]	1,191,903	2.3	487,841	68,328	637,398	6.0	15.0	7.39[j]	1.76	4.4	48½–31½	5.4
1978	1,253,543	57,798[k]	1,074,656	2.3	464,335	66,431	557,511	4.6	10.4	4.49[k]	1.40	4.1	40¼–28⅛	13.1
1977	1,123,865	41,129[l]	1,019,736	2.5	483,248	78,915	520,236	3.7	7.9	3.20[l]	1.28	3.2	51½–28	11.2
Stauffer Chemical Co.														
1980	$1,695,219	$121,743[m]	$2,084,441	1.4	$1,072,896	$246,454	$909,490	7.2%	13.4%	$2.77[m]	$1.175	6.0%	$24⅜–14½	7.0
1979	1,526,160	135,961	1,846,866	1.7	1,040,542	239,303	821,777	8.9	16.5	3.10	1.075	5.0	25–17¾	6.9
1978	1,328,114	126,015	1,635,956	2.0	903,246	201,196	730,064	9.5	17.3	2.88	0.975	4.7	24⅝–17	7.2
1977	1,232,760	116,000[n]	1,412,754	2.7	782,060	193,436	659,839	9.4	17.6	2.66[n]	0.855	4.2	25–15½	10.4

a Fiscal year ends June 30. b Excludes net gain on sale of assets of $2.0 million ($0.19 per share). c From continuing operations; excludes net income of ethical drug business of $554,000 ($0.06 per share) and net gain on sale of ethical drug business of $8.6 million ($0.91 per share). d Includes net loss from withdrawal from polyester filament business in the U.S. of $69.0 million ($1.90 per share) and from termination of interest in Aiscondel of $38.7 million ($1.07 per share). e Includes nonrecurring net charges for shutdown of European businesses of $53.2 million ($1.47 per share). f Includes net gain from divestiture of various businesses of $8.7 million. g From continuing operations; excludes net loss from discontinued Scientific Services operations of $14.5 million ($0.73 per share). h Excludes net charge for restructuring of Winchester group of $40.0 million ($1.67 per share). i Includes loss on abandonment of phenol facility of $4.4 million ($0.38 per share). j Excludes extraordinary tax credit of $7.3 million ($0.57 per share). k From continuing operations; excludes provision for loss on disposal of discontinued operations of $2.5 million ($0.19 per share). l From continuing operations; excludes losses from operations and provision for loss on disposal of discontinued operations of $2.4 million ($0.18 per share). m Excludes net gain on disposals of facilities of $14.8 million ($0.34 per share). n Includes net gain on sale of Pasadena, Tex., fertilizer plant of $3.4 million.

2 FINANCES OF THE U.S. CHEMICAL INDUSTRY

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
	Money figures in thousands of dollars unless otherwise indicated													
Stepan Chemical Co.														
1980	$157,517	$3,683[a]	$137,688	1.5	$64,338	$ 9,204	$50,498	2.3%	7.3%	$1.97[a]	$0.94	4.5%	$24½–16⅞	10.5
1979	144,981	4,794[b]	112,700	2.3	66,121	13,575	46,399	3.3	10.3	2.56[b]	0.83	4.2	23½–16⅜	7.8
1978	122,947	4,613	97,191	2.5	58,367	13,738	42,530	3.8	10.8	2.46	0.74	3.4	26⅞–16⅝	8.8
1977	108,951	5,625	81,743	2.0	49,322	16,181	38,195	5.2	14.4	3.00	0.63	3.1	24⅝–15⅝	6.7
Terra Chemicals International														
1980	$299,002	$10,279	$160,093	2.4	$34,166	$3,785	$71,711	3.4%	14.3%	$1.70	$0.20	1.4%	$19⅞–9/14	8.6
1979	254,109	2,739	137,775	2.6	35,393	2,670	63,183	1.1	4.3	0.29	0.10	1.3	10⅛–5⅛	26.3
1978	198,901	1,277	134,292	2.3	37,674	9,339	62,132	0.6	2.1	0.01	0.70	9.0	10⅞–4⅜	—
1977	109,540	7,971	121,153	2.5	32,738	9,094	65,843	7.3	12.1	1.27	0.80	7.1	13⅝–9¼	8.9
Union Carbide Corp.														
1980	$9,994,000	$573,000[c]	$9,600,000	2.1	$5,207,000	$1,129,000	$4,717,000	6.7%	14.3%	$10.08[c]	$3.10	7.1%	$52½–35¼	4.4
1979	9,176,500	556,200[d]	8,710,000	2.1	4,458,300	831,300	3,949,900	6.1	14.1	8.47[d]	2.90	7.4	44½–34	4.6
1978	7,869,700	394,300[e]	7,776,000	2.0	4,118,900	687,800	3,548,300	5.0	11.1	6.09[e]	2.80	7.3	43¼–33⅝	6.3
1977	7,036,100	385,100[f]	7,328,600	2.1	3,840,800	805,400	3,312,400	5.5	11.6	6.05[f]	2.80	5.5	62⅜–40	8.5
Williams Cos.														
1980	$2,072,686	$138,696	$2,380,001	1.8	$1,417,799	$339,625	$965,715	6.7%	14.4%	$5.07	$1.10	2.9%	$49⅜–26¾	7.5
1979	1,850,013	69,450	2,005,511	1.7	1,190,526	112,995	737,949	3.8	9.4	2.55	1.00	4.2	32¼–15	9.3
1978	1,497,008	29,534[g]	2,075,114	1.6	1,223,884	131,940	705,567	2.0	4.2	1.09[g]	1.00	5.3	23⅝–14	17.3
1977	1,239,588	65,311	1,852,044	1.9	1,153,410	164,006	685,888	5.3	9.5	2.61	1.00	4.6	25⅞–18	8.4
Witco Chemical Corp.														
1980	$1,175,695	$40,954	$612,882	2.1	$238,761	$45,663	$248,315	3.5%	16.5%	$4.50	$1.50	5.6%	$33¾–20¼	6.0
1979	966,758	42,782	551,891	1.9	192,902	40,890	222,686	4.4	19.2	4.83	1.30	5.1	30½–20	5.2
1978	751,733	33,495	405,042	1.9	166,475	31,991	189,844	4.5	17.6	3.86	1.11	5.3	24⅞–16⅝	5.4
1977	632,412	24,643	340,654	2.5	135,180	29,404	167,384	3.9	14.7	2.87	0.97	5.1	22⅝–15⅜	6.6
PHARMACEUTICALS														
Abbott Laboratories														
1980	$2,038,155	$214,413	$2,062,835	1.2	$583,214	$162,548	$1,027,222	10.5%	20.9%	$3.46	$1.20	2.6%	$ 57–34⅛	13.2
1979	1,683,168	178,981[h]	1,729,296	1.3	466,970	109,636	896,028	10.6	20.0	2.97[h]	1.00	2.7	43⅜–29½	12.3
1978	1,445,017	148,626[i]	1,453,233	1.4	403,452	84,149	773,505	10.3	19.2	2.48[i]	0.78	2.4	40–25	13.1
1977	1,244,976	117,838	1,243,458	1.6	365,504	63,935	663,694	9.5	17.8	1.98	0.575	2.4	28⅝–19½	12.1
American Home Products Corp.														
1980	$3,798,524	$445,889	$2,289,460	2.8	$450,490	$99,393	$1,391,972	11.7%	32.0%	$2.84	$1.70	6.4%	$31⅞–21⅜	9.4
1979	3,401,301	396,039	2,007,977	3.0	408,899	87,809	1,239,315	11.6	32.0	2.51	1.50	5.6	29½–24⅜	10.7
1978	3,062,633	348,422	1,779,023	2.9	369,214	67,631	1,094,798	11.4	31.8	2.21	1.325	4.5	32¾–26⅛	13.3
1977	2,685,127	306,167	1,526,072	3.0	345,336	59,628	953,036	11.4	31.1	1.94	1.15	4.0	32⅛–24⅞	14.7
Baxter Travenol Laboratories														
1980	$1,374,384	$128,400	$1,412,638	2.8	$560,690	$118,645	$852,606	9.3%	15.1%	$3.72	$0.64	1.4%	$56⅝–35¾	12.4
1979	1,191,193	111,908[j]	1,290,928	2.3	500,976	103,654	723,510	9.4	15.5	3.29[j]	0.50	1.2	49½–35⅜	12.9
1978	1,004,196	91,683[k]	1,129,637	2.2	445,223	90,057	612,231	9.1	15.0	2.73[k]	0.40	1.0	49¾–32⅝	15.1
1977	844,446	75,120	964,189	2.5	383,754	83,776	518,968	8.9	14.5	2.27	0.285	0.8	40⅞–28¼	15.7
Bristol-Myers Co.														
1980	$3,158,300	$270,600	$2,125,500	2.3	$484,900	$131,600	$1,296,200	8.6%	20.9%	$4.08	$1.56	3.8%	$ 52–30½	10.1
1979	2,752,777	231,545	1,837,648	2.4	407,528	95,022	1,117,002	8.4	20.7	3.50	1.385	4.0	38¼–31	9.9
1978	2,450,429	203,048	1,619,015	2.3	358,515	81,922	981,624	8.3	20.7	3.08	1.19	3.5	40⅜–28	11.1
1977	2,191,433	174,261	1,422,181	2.3	313,846	70,439	839,279	8.0	20.8	2.72	1.05	3.2	35⅞–28¾	11.9
Eli Lilly & Co.														
1980	$2,558,637	$341,974	$2,607,452	2.0	$849,034	$230,700	$1,736,693	13.4%	19.7%	$4.52	$2.20	4.0%	$65½–45¾	12.3
1979	2,205,764	329,531	2,179,132	2.4	672,610	172,678	1,570,439	14.9	21.0	4.52	1.95	3.5	63⅞–47⅛	12.3
1978	1,852,090	277,475	2,049,901	2.1	551,657	89,550	1,384,082	15.0	20.0	3.81	1.65	3.6	54–36⅝	11.9
1977	1,518,012	218,684	1,739,980	2.4	503,801	78,157	1,195,986	14.4	18.3	3.10	1.42	3.5	48¼–32⅝	13.0

a Excludes net gain on sale of Polychem department of $1.7 million ($0.93 per share). b Excludes nonrecurring net gain on sale of fragrance business of $528,000 ($0.28 per share). c Excludes cumulative effect of change in accounting principle for the investment tax credit of $217 million ($3.28 per share), but includes net gain on sales and disposals of assets of $14 million. d Includes net charge on sales and disposals of assets of $21.1 million. e Includes net gain on sales of European ethylene derivatives business and other businesses of $54.4 million. f Includes net gain on sales and disposals of assets of $17.8 million. g From continuing operations; excludes net loss from discontinued and disposed of operations of $16.7 million ($0.62 per share). h Includes net gain on sale of animal health business of $1.8 million ($0.02 per share). i Includes net gain on sale of blood products business of $3.3 million ($0.03 per share). j Includes net gain on sale of assets of $450,000. k Includes net gain on sale of enzyme facilities of $700,000.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
					Money figures in thousands of dollars unless otherwise indicated									
Merck & Co.														
1980	$2,734,012	$415,396	$2,865,755	2.3	$1,185,244	$256,488	$1,863,322	15.2%	22.3%	$5.54	$2.30	3.2%	$ 86–58¼	13.0
1979	2,384,627	381,775	2,614,064	2.2	1,027,644	170,134	1,665,496	16.0	22.9	5.06	1.90	2.8	74¼–62½	13.5
1978	1,981,440	307,534	2,251,348	2.4	924,179	155,853	1,455,135	15.5	21.1	4.07	1.70	2.9	69¼–47⅜	14.3
1977	1,724,410	277,525[a]	1,993,389	2.5	846,784	177,167	1,277,753	16.1	21.7	3.67[a]	1.50	2.5	68¼–50	16.1
Morton-Norwich Products														
1980[b]	$846,601	$47,730	$590,077	2.1	$250,911	$52,094	$316,902	5.6%	15.1%	$3.52	$1.40	5.1%	$ 34–21¼	7.8
1979[b]	731,984	46,088	566,039	2.6	223,224	48,593	297,777	6.3	15.5	3.40	1.26	4.2	34⅞–25¾	8.8
1978[b]	656,733	36,938	504,465	3.2	195,337	29,139	272,027	5.6	13.6	2.85	1.11	3.8	34⅞–23½	10.2
1977[b]	609,303	31,683	457,851	3.0	188,100	29,702	229,642	5.2	13.8	2.51	0.91	3.8	29½–18⅝	9.5
Pfizer Inc.														
1980	$3,029,300	$254,800	$3,247,300	1.9	$825,000	$163,600	$1,456,500	8.4%	17.5%	$3.48	$1.44	3.4%	$53¾–32	12.3
1979	2,746,025	237,869	2,945,280	2.0	759,269	133,300	1,310,074	8.7	18.2	3.26	1.32	3.7	41¾–29	10.9
1978	2,362,133	206,256	2,643,611	2.0	709,957	110,100	1,149,537	8.7	17.9	2.93	1.17	3.6	39–25½	11.0
1977	2,031,925	175,395	2,368,825	1.9	681,213	91,100	1,042,764	8.6	16.8	2.50	0.99	3.7	29½–23⅝	10.6
Richardson-Vicks[c]														
1980[b]	$1,211,651	$84,209	$829,551	2.0	$242,568	$52,630	$427,938	6.9%	19.7%	$3.56	$1.20	4.3%	$38⅛–17½	7.8
1979[b]	1,090,546	62,956	718,229	2.1	209,251	47,545	376,852	5.8	16.7	2.66	1.06	4.5	27–19¾	8.8
1978[b]	944,961	66,179	631,801	2.0	192,413	29,681	333,005	7.0	19.9	2.80	0.90	3.5	31–19⅞	9.1
1977[b]	836,004	57,180	564,287	2.5	173,283	27,550	314,701	6.8	18.2	2.42	0.70	3.1	26¼–18¾	9.3
A. H. Robins Co.														
1980	$432,328	$25,470[d]	$337,318	2.9	$80,511	$30,273	$227,142	5.9%	11.2%	$1.01[d]	$0.42	4.4%	$12½–6⅝	9.5
1979	386,425	44,746[e]	329,072	2.8	59,994	16,687	222,148	11.6	20.1	1.71[e]	0.40	4.0	12–8¼	5.9
1978	357,070	29,916	273,895	3.6	55,350	12,643	188,097	8.4	15.9	1.15	0.34	3.2	12⅞–8⅝	9.3
1977	306,713	26,801	233,401	3.4	49,751	11,601	165,598	8.7	16.2	1.03	0.32	2.7	14¼–9½	11.5
Schering-Plough Corp.														
1980	$1,740,400	$239,300	$1,925,800	1.7	$524,800	$130,900	$1,193,800	13.7%	20.0%	$4.45	$1.56	4.2%	$45⅝–29⅛	8.4
1979	1,434,022	222,267	1,534,245	2.0	415,401	68,316	1,037,354	15.5	21.4	4.12	1.39	4.4	35¼–27½	7.6
1978	1,082,493	193,629	1,183,919	2.7	319,551	51,336	848,558	17.9	22.8	3.62	1.21	3.8	38–26¼	8.9
1977	940,859	166,652	1,055,087	2.4	295,284	51,572	803,675	17.7	20.7	3.08	1.09	3.0	44¾–27⅞	11.8
G. D. Searle & Co.														
1980	$1,081,558	$94,341[f]	$1,089,920	1.4	$249,695	$66,961	$508,844	8.7%	18.5%	$1.78[a]	$0.52	2.3%	$27⅝–17¼	12.6
1979	898,369	89,004[g]	1,099,383	1.9	212,972	49,253	456,358	9.9	19.5	1.68[g]	0.52	3.3	20–11½	9.4
1978	848,380	72,187	964,962	3.1	179,710	40,413	414,983	8.5	17.4	1.37	0.52	3.8	16⅝–10⅝	9.9
1977	846,931	30,610[h]	949,857	2.3	191,662	43,873	371,346	3.6	8.2	0.59[h]	0.52	4.2	13¾–10⅞	20.9
SmithKline Corp.														
1980	$1,771,938	$307,994	$1,490,914	2.4	$421,788	$132,806	$923,723	17.4%	33.3%	$4.65	$1.725	2.8%	$80⅝–43½	13.3
1979	1,351,145	233,837	1,150,260	2.3	289,847	93,494	667,468	17.3	35.0	3.85	1.32	2.6	63¼–38½	13.2
1978	1,112,039	164,075	894,224	2.4	224,929	75,579	503,770	14.8	32.6	2.72	0.78	2.1	51¼–23⅛	13.6
1977	780,337	89,271	702,199	2.4	176,936	45,216	376,260	11.4	23.7	1.49	0.54	2.7	25¼–15⅝	13.6
Squibb Corp.														
1980	$1,675,780	$123,079[i]	$1,858,270	2.3	$600,895	$ 89,032	$964,504	7.3%	12.8%	$2.56[j]	$1.155	3.6%	$39¼–24⅜	12.4
1979	1,782,894	123,722	1,747,688	2.2	630,047	109,970	881,875	6.9	14.0	2.71	1.095	3.3	39¼–27	12.2
1978	1,515,882	117,255	1,541,165	2.2	559,090	108,046	793,219	7.7	14.8	2.60	1.035	3.5	37⅜–21⅜	11.3
1977	1,341,583	112,508	1,392,269	2.2	486,519	109,332	721,000	8.4	15.6	2.50	0.975	3.8	30½–21⅜	10.4
Sterling Drug														
1980	$1,701,433	$123,337	$1,214,231	2.4	$318,109	$70,051	$752,640	7.2%	16.4%	$2.04	$0.90	4.2%	$26⅞–16	10.5
1979	1,500,692	111,594	1,105,581	2.3	280,594	58,186	680,649	7.4	16.4	1.85	0.82	4.5	21⅜–15¼	9.9
1978	1,314,630	94,675	959,470	2.5	255,603	36,933	618,767	7.2	15.3	1.57	0.75	4.7	19¼–12¾	10.2
1977	1,183,569	85,829	871,869	2.5	244,498	38,640	567,895	7.3	15.1	1.43	0.70	4.6	17–13⅛	10.5
Upjohn Co.														
1980	$1,760,576	$170,375	$1,660,621	1.9	$544,322	$109,800	$865,753	9.7%	19.7%	$5.71	$1.93	3.5%	$ 68–41½	9.6
1979	1,508,025	149,478	1,403,734	2.1	476,367	77,498	743,659	9.9	20.1	5.03	1.62	3.6	50½–40	9.0
1978	1,328,551	129,405	1,207,625	2.3	437,803	44,681	639,753	9.7	20.2	4.36	1.37	3.1	56–32⅛	10.1
1977	1,134,325	91,521	1,048,179	2.6	429,305	41,425	548,989	8.1	16.7	3.09	1.17	3.4	38⅞–30	11.1
Warner-Lambert Co.														
1980	$3,479,207	$192,716[l]	$2,638,077	2.1	$827,131	$138,888	$1,171,477	5.5%	16.5%	$2.41[l]	$1.32	6.6%	$23¼–17	8.4
1979	3,217,208	123,346[k]	2,542,167	1.9	775,253	155,473	1,067,151	3.8	11.6	1.55[k]	1.29	5.8	26½–17⅝	14.3
1978	2,878,496	207,947	2,318,839	2.0	715,880	133,748	1,026,713	7.2	20.3	2.61	1.175	4.2	32½–22⅞	10.6
1977	2,542,728	187,816	1,965,969	2.6	590,014	103,494	1,117,896	7.4	16.8	2.36	1.075	3.9	31⅝–23⅞	11.8

a Excludes extraordinary net gain on sale of Calgon consumer products business of $13.2 million ($0.18 per share). b Fiscal year ends June 30. c Data for Richardson-Merrell prior to sale in March 1981 of ethical pharmaceutical businesses to Dow Chemical Co. d Includes income, before taxes, from litigation settlement of $3.6 million and provision for net losses on disposition of businesses of $4.7 million ($0.19 per share). e Includes income, before taxes, from settlement of antitrust litigation of $28.9 million. f From continuing operations; excludes reserve for loss from sale of assets of diagnostic businesses of $9.0 million ($0.17 per share) and extraordinary tax credit of $13.0 million ($0.24 per share). g From continuing operations; excludes net loss from operations of divested diagnostic businesses of $1.1 million ($0.02 per share). h Excludes provision for loss on disposal of assets of businesses being divested of $59.0 million ($1.12 per share). i From continuing operations; excludes net income of divested food services and related operations of $4.3 million ($0.09 per share). j Includes net nonrecurring charge of $3 million ($0.03 per share). k Includes net nonrecurring charges and tax settlement of $64 million ($0.80 per share).

Lower capacity use stunts productivity growth

Along with most other economic measures of U.S. chemical industry performance in 1980, productivity suffered considerably, leading to a big increase in unit labor costs. A big part of the problem was low levels of plant use.

In 1980, for the first time in more than a decade, the chemical industry had no gain at all in labor productivity (output per workhour). As in the previous recession year of 1975, chemical productivity fell below growth in all manufacturing, which came in at 2% in 1980. By contrast, the average annual increase over the past decade has been 5% in the chemical industry and 4% in all manufacturing.

With no help from productivity, the chemical industry's unit labor costs shot up 9% in 1980, more than the 6% increase in all manufacturing. These jumps are also out of line with average annual increases of 3% in the chemical industry and 5% in all manufacturing over the past decade.

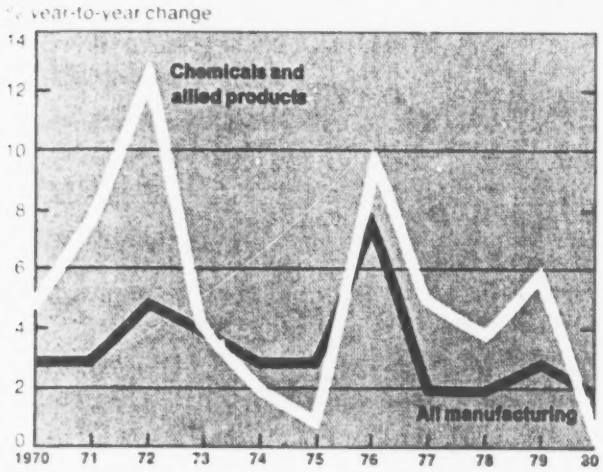
The chemical industry plant output sank sharply in the 1980 recession, hitting a low point of 67% of nameplate capacity for leading basic chemicals in the third quarter. Since then, the plant-use rate recovered to 74% in the first quarter of 1981. However, plant use is still below 70% for many important products, including more than half of the organics.

PRODUCTIVITY: Chemical industry and all manufacturing have off-year in 1980

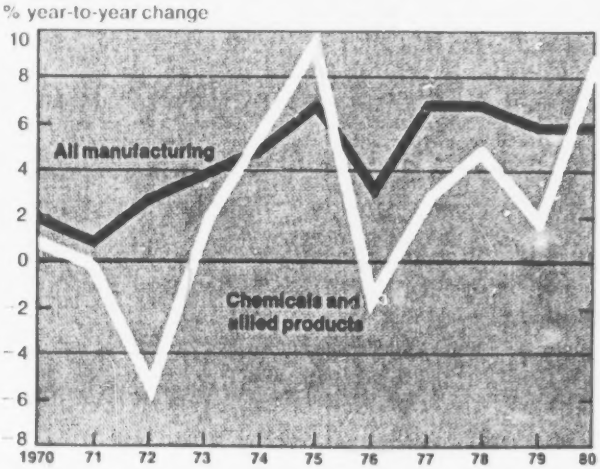
Indexes, 1967 = 100	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
CHEMICALS AND ALLIED PRODUCTS											
Production	206.7	211.8	197.4	185.7	170.9	147.2	159.4	154.4	143.6	125.9	120.4
Workhours	105.5	107.7	106.8	104.5	101.4	96.5	105.1	103.7	100.3	99.2	102.0
Productivity	195.9	196.7	184.8	177.7	168.5	152.5	151.7	149.0	143.2	126.9	118.0
Hourly production wages	267.4	245.2	226.5	207.4	190.7	173.9	157.4	145.5	137.4	128.0	119.0
Unit labor costs	136.5	124.7	122.6	116.7	113.2	114.0	103.8	97.7	96.0	101.0	100.9
ALL MANUFACTURING											
Production	146.6	153.6	146.8	138.4	130.3	116.3	129.4	129.8	118.9	108.2	106.4
Workhours	97.6	104.4	102.6	98.2	94.2	88.6	100.9	104.0	98.1	93.0	96.3
Productivity	150.2	147.0	143.1	140.9	138.3	128.3	124.8	121.2	116.3	110.5	107.5
Hourly production wages	257.8	237.2	218.8	201.4	185.1	171.3	156.7	145.0	135.5	126.6	118.8
Unit labor costs	171.6	161.4	152.9	142.9	133.8	130.5	122.1	116.2	111.8	108.9	107.5

Sources: Department of Labor, Federal Reserve Board, C&EN calculations

Productivity was unchanged in chemicals . . .



. . . while unit labor costs shot up



Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources:** Department of Labor, Federal Reserve Board, C&EN calculations

OPERATING RATES: Use of chemical plant capacity is recovering after 1980 dive

Billions of lb per year unless otherwise noted[a]	1ST-QTR Capacity[b]	1981 Use	3RD-QTR Capacity[b]	1980 Use	1ST-QTR Capacity[b]	1980 Use	3RD-QTR Capacity[b]	1979 Use	1ST-QTR Capacity[b]	1979 Use	3RD-QTR Capacity[b]	1978 Use
ORGANIC CHEMICALS												
Benzene (bg)	2.5	68%	2.4	64%	2.6	70%	2.3	77%	2.3	70%	2.2	67%
Butadiene[c]	4.6	61	4.0	65	4.7	75	4.0	90	4.3	78	4.3	82
Cyclohexane	3.4	62	3.4	52	3.2	85	3.2	78	3.2	76	3.2	63
DMT-TPA[d]	7.3	71	7.3	59	7.3	75	7.3	68	7.3	68	6.6	72
Ethylene	40.0	68	40.0	63	37.0	84	36.5	89	35.2	85	32.5	80
Formaldehyde, 37% solution	8.9	66	8.6	59	8.5	72	8.5	79	8.5	79	8.7	74
Methanol (bg)	1.4	90	1.4	80	1.4	83	1.4	85	1.4	78	1.4	71
Phenol	3.6	69	3.7	65	3.6	81	3.4	82	3.4	82	3.5	75
Propylene, chemical	23.5	58	23.7	48	20.5	79	20.5	72	20.0	72	19.0	68
Propylene oxide	2.7	62	2.7	48	3.0	66	3.0	83	3.0	85	3.0	67
Styrene	8.9	82	8.9	55	9.3	87	8.4	89	8.2	88	8.7	80
Urea	8.0	88	8.0	91	7.7	86	7.5	87	7.5	80	6.2	82
Vinyl acetate	2.5	78	2.5	68	2.5	79	2.4	83	2.2	82	2.1	81
Vinyl chloride	9.7	66	8.2	63	8.7	89	8.4	99	8.8	90	8.8	71
***p*-Xylene**	5.6	86	5.6	68	5.3	70	5.7	79	4.3	84	4.3	71
INORGANIC CHEMICALS												
Ammonia (mt)	24.0	83	24.0	75	20.4	95	20.4	91	21.0	74	19.0	88
Carbon black	3.7	76	3.7	61	3.8	68	4.3	73	4.3	91	4.0	83
Carbon dioxide (ttd)	15.6	69	15.6	68	14.1	69	12.5	52	12.5	65	15.7	51
Caustic soda (mt)	15.6	73	15.3	68	15.5	79	15.1	85	15.0	76	14.6	77
Chlorine (mt)	14.7	73	14.6	69	14.4	84	14.4	88	14.3	83	13.9	81
Nitrogen / **Oxygen** } total, liquid (ttd)	34.8	63	33.6	69	32.4	68	31.2	67	30.7	67	31.5	57
Phosphoric acid, (P_2O_5) (mt)	11.7	94	11.7	87	11.0	94	9.8	94	10.2	95	9.8	88
Phosphorus (mt)	0.55	78	0.55	70	0.55	83	0.55	78	0.55	83	0.55	82
Soda ash (mt)	10.0	82	9.7	79	9.7	85	9.1	92	8.6	90	9.4	87
Sulfuric acid (mt)	58.3	74	58.0	76	57.5	76	56.0	81	56.0	75	55.5	67
Titanium dioxide (mt)	1.0	77	1.0	66	1.0	75	0.88	88	0.88	82	0.94	80
AVERAGE		**74%**		**67%**		**79%**		**82%**		**80%**		**75%**

a bg = billions of gallons, mt = millions of tons, ttd = thousands of tons per day. b Nameplate capacity. c Based on extraction capacity of steam-cracking olefins plants, dehydrogenation and extraction capacity of dehydrogenation plants, and other butadiene recovery capacity. d Dimethyl terephthalate-purified terephthalic acid, not including acid converted to dimethyl terephthalate.
Sources: Industry sources, C&EN estimates

Surplus capacity increased in chemical process industries last year

	Operating rate, % of nameplate capacity, as of December										
	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
Chemicals	78%	83%	83%	76%	78%	78%	81%	88%	85%	81%	80%
Paper	89	91	89	87	85	85	84	93	91	87	86
Petroleum	80	86	91	91	93	91	90	95	94	93	95
Rubber	70	70	84	81	85	81	77	84	89	86	83
Textiles	80	82	85	87	84	85	69	89	91	86	81
All manufacturing	78	81	84	82	81	79	78	85	85	80	80

Source: Department of Commerce

ENERGY USE BY CHEMICAL INDUSTRY: **Gas and electricity account for two thirds**

	1980		1979		1978		1977		1972		Change 1972–80	
Energy source[a]	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	%
Natural gas	1293	39.8%	1371	38.6%	1237	37.1%	1306	39.4%	1618	47.5%	−325	−20.1%
Purchased electricity[b]	943	29.0	998	28.1	876	26.3	848	25.6	767	22.5	176	22.9
Petroleum-based fuels	621	19.1	762	21.5	800	24.0	746	22.5	578	17.0	43	7.5
Light hydrocarbons[c]	380	11.7	433	12.2	370	11.1	301	9.1	290	8.5	91	31.4
Residual fuels	141	4.3	217	6.1	269	8.1	241	7.3	185	5.4	−45	−24.1
Distillate fuels	23	0.7	37	1.0	64	1.9	79	2.4	35	1.0	−12	−34.9
Other fuel[d]	77	2.4	75	2.1	98	2.9	124	3.8	68	2.0	9	13.5
Coal and coke	300	9.2	305	8.6	305	9.1	295	8.9	333	9.8	−33	−9.8
Purchased steam	95	2.9	115	3.2	117	3.5	120	3.6	111	3.3	−15	−13.9
TOTAL	**3254**	**100.0%**	**3550**	**100.0%**	**3335**	**100.0%**	**3315**	**100.0%**	**3408**	**100.1%**	**−154**	**−4.5%**

a For energy and process use only, excluding energy equivalent of feedstock. b Electricity is calculated as fuel value of 10,000 Btu to generate 1 kWh instead of using standard conversion factor of 3412 Btu per kWh. c Includes propane, liquefied petroleum gas, and other gases. d Includes petroleum coke, gasoline, and other liquids and solids. **Note:** Data from companies accounting for more than 80% of U.S. capacity for basic industrial chemicals. **Source:** Chemical Manufacturers Association

ENERGY USE BY FERTILIZER INDUSTRY: **Gas is by far the most important source**

	1980		1979[b]		1972		Change 1972–80	
Energy Source[a]	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	%
Natural gas	205.0	79.3%	206.1	77.9%	167.6	79.8%	37.3	22.3%
Purchased electricity[c]	46.9	18.2	49.2	18.6	35.4	16.9	11.5	32.6
Petroleum-based fuels	5.8	2.2	8.6	3.3	6.0	2.9	−0.2	−3.9
Light hydrocarbons[d]	0.4	0.2	0.4	0.1	0.1	0	0.3	406.9
Residual fuels	4.5	1.7	5.4	2.0	3.2	1.5	1.3	42.2
Distillate fuels	0.7	0.3	2.7	1.0	1.8	0.9	−1.2	−63.1
Other fuel[e]	0.2	0.1	0.2	0.1	1.0	0.5	−0.8	−79.2
Coal and coke	0.6	0.2	0.5	0.2	0.9	0.4	−0.3	−34.6
Purchased steam	0.2	0.1	0.2	0.1	0.1	0	0.1	127.4
TOTAL	**258.5**	**100.0%**	**264.6**	**100.1%**	**210.1**	**100.0%**	**48.4**	**23.1%**

a For energy and process use only, excluding energy equivalent of feedstock. b Figures for 1979 include 18 companies (with total energy consumption of 209 trillion Btu) that use 1972 as a reference base and four companies (with total energy consumption of 56 trillion Btu) that use 1978 as a reference base instead; 1979 figures are thus not completely comparable to other years. c Electricity is calculated as fuel value of 10,000 Btu to generate 1 kWh instead of using standard conversion factor of 3412 Btu per kWh. d Includes propane and liquefied petroleum gas. e Includes gasoline, diesel oil, kerosene, and other fuels. **Note:** Data from companies accounting for more than 70% of U.S. fertilizer capacity. **Source:** The Fertilizer Institute

ENERGY USE BY PETROLEUM INDUSTRY: **Oil accounts for nearly two thirds of total**

	1980		1979		1978		1977		1972		Change 1972–80	
Energy source[a]	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	%
Natural gas	734	25.1%	758	25.0%	676	22.6%	761	25.2%	1037	33.3%	−303	−29.2%
Purchased electricity[b]	253	8.6	242	8.0	231	7.7	230	7.6	200	6.4	53	26.3
Petroleum-based fuels	1903	65.1	1989	65.7	2050	68.4	1978	65.5	1832	58.9	70	3.8
Light hydrocarbons[c]	1243	42.5	1291	42.7	1287	42.9	1192	39.5	1091	35.1	153	14.0
Residual fuels	215	7.3	234	7.7	306	10.2	311	10.3	268	8.6	−53	−19.9
Petroleum coke	425	14.5	431	14.3	422	14.1	444	14.7	445	14.3	−19	−4.4
Other fuel[d]	19	0.7	33	1.1	35	1.2	30	1.0	29	0.9	−10	−33.1
Coal and coke	4	0.1	5	0.2	3	0.1	10	0.3	5	0.2	−1	−20.7
Purchased steam	31	1.1	32	1.1	38	1.3	38	1.3	37	1.2	−6	−15.7
TOTAL	**2925**	**100.0%**	**3026**	**100.0%**	**2998**	**100.1%**	**3018**	**99.9%**	**3111**	**100.0%**	**−186**	**−6.0%**

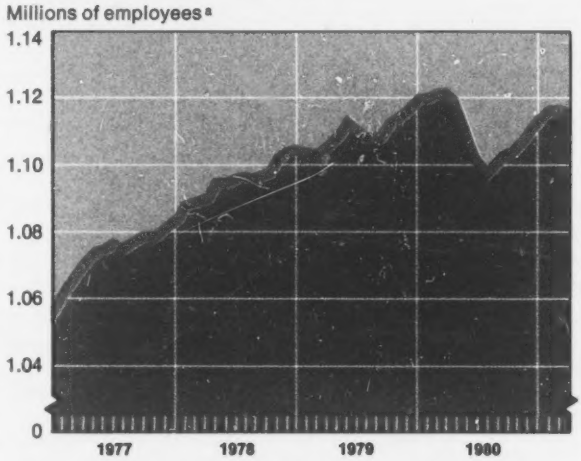
a For energy and process use only, excluding energy equivalent of feedstock. b Electricity is calculated as fuel value of 10,000 Btu to generate 1 kWh instead of using standard conversion factor of 3412 Btu per kWh. c Includes propane, liquefied petroleum gas, and refinery gas. d Includes distillate fuels, gasoline, and other liquids. **Note:** Data from companies accounting for more than 90% of U.S. petroleum refining capacity. **Source:** American Petroleum Institute

Chemical employment little changed in 1980

Compared to some other major industries—construction and automobiles, for example—employment tends to be relatively stable in the chemical industry. Last year provides good evidence; despite the recession, few chemical workers were laid off. From the peak levels of early spring, the number of workers on the job last year in chemical operations fell less than 25,000—about 2%—by late summer. That's only a third the job loss that took place during the previous recession five years earlier. And by early this past spring, employment had bounced back nearly to the year-earlier total.

For 1980 as a whole, as a result, average employment was nearly unchanged in the entire industry. And for the more susceptible blue-collar workers, the annual average number of job holders was down only 1%. Employment of scientists and engineers, meanwhile, increased about 5%.

Jobs edge upward in chemical industry following mid-1980 dip



a Seasonally adjusted employment in U.S. chemicals and allied products industry; March and April 1981 figures are preliminary.
Source: Department of Labor

INDUSTRIAL EMPLOYMENT: Almost unchanged in chemical industry in 1980

	All employees[a] (thousands)				Production workers[a] (thousands)				Workweek[a,b] (hours)			
	1980	1979	1978	1970	1980	1979	1978	1970	1980	1979	1978	1970
All manufacturing	20,361	21,062	20,505	19,367	14,277	15,085	14,734	14,044	39.7	40.2	40.4	39.8
Chemicals and allied products	1,113	1,111	1,096	1,049	627	633	628	604	41.5	41.9	41.9	41.6
Industrial inorganic chemicals	166	163	164	na	89	88	93	na	41.5	42.1	42.2	na
Plastics materials and synthetics	204	211	214	232	135	143	145	143	41.4	42.1	42.4	41.8
Drugs	199	193	187	149	98	96	90	73	41.0	41.1	41.3	40.5
Soap, cleaners, and toilet goods	138	139	136	127	84	84	83	73	40.4	40.4	40.6	41.0
Paints and allied products	67	69	69	70	34	36	36	39	40.3	41.2	41.5	40.5
Industrial organic chemicals	173	172	168	na	88	89	87	na	42.8	43.4	42.5	na
Agricultural chemicals	72	70	67	na	45	45	42	na	43.3	42.9	42.6	na
Miscellaneous chemical products	95	93	90	na	54	53	51	na	41.0	41.5	41.6	na
Petroleum and coal products	197	210	208	191	124	137	136	118	41.8	43.8	43.6	42.8
Rubber and miscellaneous plastics products	711	776	754	580	548	607	591	444	40.1	40.5	40.9	40.2

a Domestic employment. b Workweek of production or nonsupervisory workers. na = not available. **Source:** Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: Up more than 10,000 in chemicals since 1970

Thousands[a]	1980[b]	1979[c]	1978	1977	1976	1975	1974	1973	1972	1971	1970
Total, all industry	444.5	421.0	403.7	382.8	364.4	363.3	360.0	357.7	350.2	367.0	384.2
Chemicals and allied products	50.9	48.3	47.9	46.4	44.4	45.2	41.8	40.9	41.0	42.7	40.1
Industrial chemicals	22.1	21.6	21.5	20.6	20.1	21.1	19.1	19.1	19.1	21.8	21.5
Drugs and medicines	20.7	19.7	18.9	17.8	16.6	15.6	14.0	13.0	13.1	12.3	11.8
Other chemicals	8.1	7.0	7.4	8.0	7.8	8.5	8.7	8.8	8.8	8.6	6.8
Petroleum refining	10.7	10.7	10.0	8.9	8.6	8.4	8.2	8.2	8.3	9.2	9.9
Rubber products	9.2	8.0	7.9	9.1	8.6	8.4	7.7	7.5	6.7	6.7	7.4

a Full-time-equivalent number of R&D scientists and engineers in industry, as of January of each year. b Preliminary. c Preliminary revision. **Source:** National Science Foundation

CHEMICAL EMPLOYMENT: Sales per employee top $100,000 in 1980

Thousands	Worldwide employment 1980	1979	1978	1977	1976	1975	1974	1973	1972	1971
Air Products	15.8	14.6	14.3	13.7	13.4	13.0	13.0	10.3	9.0	9.2
Akzona	15.9	15.4	15.3	15.6	15.6	15.8	19.5	19.6	17.7	16.6
Allied Corp.	46.3	49.0	32.0	32.8	33.4	33.4	32.2	33.5	32.7	34.0
American Cyanamid	42.6	44.2	44.0	43.8	39.4	37.8	38.0	39.5	41.4	41.4
Celanese	36.5	33.3	33.2	32.1	31.9	37.0	38.8	37.4	36.2	36.5
Crompton & Knowles	2.8	3.0	3.2	3.1	3.0	2.2	2.4	2.5	2.6	2.8
Diamond Shamrock	12.7	12.4	12.9	12.3	11.4	10.9	9.8	9.3	8.7	8.5
Dow Chemical	56.8	55.9	53.5	53.2	53.0	53.0	53.3	49.8	48.8	47.8
Du Pont	135.9	134.2	131.8	132.0	132.5	134.6	135.2	129.1	122.3	127.2
Ethyl Corp.	15.0	16.0	16.5	16.0	16.0	17.0	18.0	14.0	14.0	13.0
Freeport Minerals	2.7	3.9	3.5	3.7	3.8	3.5	3.3	2.9	2.3	2.3
W. R. Grace	91.7	82.1	68.5	68.7	63.8	65.3	79.1	75.7	73.9	66.9
Hercules	22.9	24.4	24.5	24.0	24.0	23.5	25.3	24.1	22.4	22.1
International Flavors	3.6	3.6	3.5	3.3	3.1	2.9	3.1	2.8	2.7	2.7
International Minerals	10.6	10.3	9.9	9.9	9.7	10.5	6.6	6.2	6.2	7.0
Lubrizol	4.2	3.9	3.8	3.6	3.6	3.6	3.5	3.3	3.0	3.0
Mallinckrodt	4.8	4.8	4.9	4.3	4.3	3.9	3.7	3.1	2.9	2.8
Monsanto	61.8	63.9	62.9	61.5	61.9	59.2	60.9	58.3	57.9	59.3
Nalco Chemical	4.4	4.1	4.1	4.2	3.8	3.5	3.4	3.2	2.9	2.7
Olin	21.0	21.7	22.7	22.4	22.0	23.0	23.0	24.0	32.0	31.0
Pennwalt	12.8	13.3	14.0	13.9	13.9	14.3	14.8	13.9	12.8	13.0
Reichhold Chemicals	5.6	6.4	6.5	6.5	5.8	4.3	4.1	4.3	3.4	3.4
Rohm & Haas	13.2	13.3	13.1	13.0	13.3	13.8	14.2	13.5	13.1	12.7
Stauffer Chemical	13.4	13.8	13.1	13.0	13.0	13.1	12.5	12.0	11.3	10.5
Stepan Chemical	0.8	0.9	0.8	0.8	0.7	0.7	0.8	0.7	0.6	0.6
Texasgulf	6.5	5.9	5.5	5.4	5.3	4.9	4.3	4.0	3.8	3.3
Union Carbide	116.1	115.8	113.4	113.7	113.1	106.5	109.6	109.4	98.1	99.2
TOTAL EMPLOYEES	776.4	770.1	735.5	726.5	715.1	711.3	732.4	706.5	690.5	682.0
ANNUAL CHANGE	0.8%	4.7%	1.2%	1.6%	0.5%	−2.9%	3.7%	2.3%	1.2%	0.6%
SALES PER EMPLOYEE ($ thousands)	$106.9	$96.6	$89.9	$75.3	$69.1	$53.5	$57.9	$45.7	$40.7	$35.6

Note: Data for years prior to 1980 are not restated for acquisitions and similar adjustments.

WAGES: Better than national average for chemical blue-collar workers

	Hourly earnings[a] 1980	1979	1978	1970	Weekly earnings[a] 1980	1979	1978	1970
All manufacturing	$7.27	$6.69	$6.17	$3.35	$288.62	$268.94	$249.27	$133.33
Chemicals and allied products	8.29	7.59	7.01	3.69	344.04	317.26	293.72	153.50
Industrial inorganic chemicals	9.06	8.26	7.63	na	375.99	347.75	321.99	na
Plastics materials and synthetics	8.26	7.41	6.87	3.62	341.96	311.96	291.29	151.32
Drugs	7.67	6.94	6.42	3.54	314.47	285.23	265.15	143.37
Soap, cleaners, and toilet goods	7.56	7.18	6.69	3.64	305.42	290.79	271.61	149.24
Paints and allied products	7.40	6.78	6.34	3.48	298.22	278.66	263.11	140.88
Industrial organic chemicals	9.66	9.01	8.22	na	413.45	391.03	349.35	na
Agricultural chemicals	8.11	7.29	6.68	na	351.16	312.74	248.57	na
Miscellaneous chemical products	7.76	7.07	6.54	na	318.16	293.41	272.06	na
Petroleum and coal products	10.09	9.37	8.63	4.28	421.76	410.41	376.27	183.18
Rubber and miscellaneous plastics products	6.49	5.96	5.52	3.20	260.25	241.38	225.77	128.64

a For production and nonsupervisory workers in domestic employment. na = not available. **Source:** Department of Labor

U.S. chemical trade surplus widens again

U.S. trade balance improved last year for the second consecutive year. That is something that hasn't happened since 1970.

True, last year's improvement wasn't much—a mere $500 million. And the balance was still in deficit to the tune of $24.2 billion.

But given the recent string of mounting deficits, any improvement is welcome news for U.S. trade officials. Hidden behind the bare statistics are some rather encouraging signs.

One is the trend in oil imports, the chief culprit in the U.S. trade picture. Last year, imports of crude oil and petroleum products cost the U.S. $78.6 billion, 38% more than in 1979. But that increase is only the result of the higher prices that prevailed last year. Certainly, the trade deficit would have grown worse had it not been for a 15% drop in the volume of crude and petroleum products imports.

Eliminate the cost of imported oil and it becomes apparent that U.S. export of agricultural and manufactured products is more than holding its own against imports. Were it not for the oil that it had to import, the U.S. would have enjoyed a trade surplus of $54.3 billion in 1980.

Nowhere (other than in agricultural commodities) is the U.S. export strength more obvious than in chemicals. Chemical exports grew almost 20% last year and topped $20 billion for the first time. Imports grew only about 15% and, as a result, the chemical trade surplus increased to a staggering $12.7 billion.

The chemical industry has been setting new records for its trade surplus for the past eight years. Whether it will do it again this year remains to be seen. The industry now is losing some of its heralded feedstock and price advantage. The economies of many nations that are important export markets are weak and not conducive to increased exports. New competition from foreign producers is cropping up in world markets. But the industry has managed to surprise the prophets of doom before. It may do so again.

U.S. TOTAL TRADE BALANCE:
Deficit declined slightly last year

$ Millions	1980	1979	1978	1970
Exports[a]	$220,626	$181,639	$143,575	$42,659
Imports[b]	244,871	206,327	172,026	39,952
Trade balance	−24,245	−24,688	−28,451	2,707

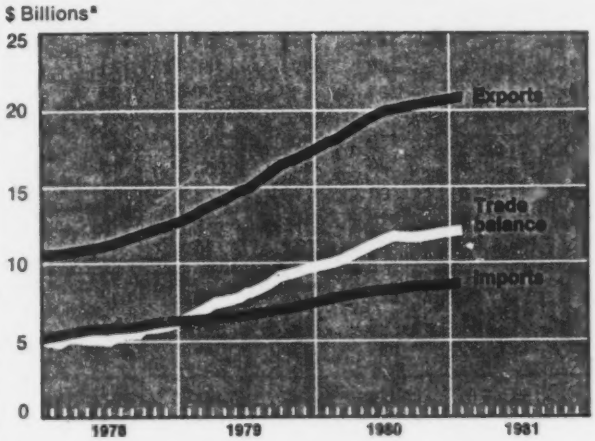
a Exports of domestic and foreign merchandise, excluding Department of Defense and Grant-Aid shipments; FAS (free along ship) value. b General imports; starting with 1974 reported as FAS value, prior to 1974 reported as foreign value, which is within 1% of FAS value.

U.S. CHEMICAL TRADE BALANCE:
Surplus continues to increase strongly

$ Millions	1980	1979	1978	1970
Chemical exports[c]	$20,740	$17,306	$12,618	$3,826
Chemical imports[b]	8,583	7,485	6,427	1,450
Chemical trade balance	12,157	9,821	6,191	2,376

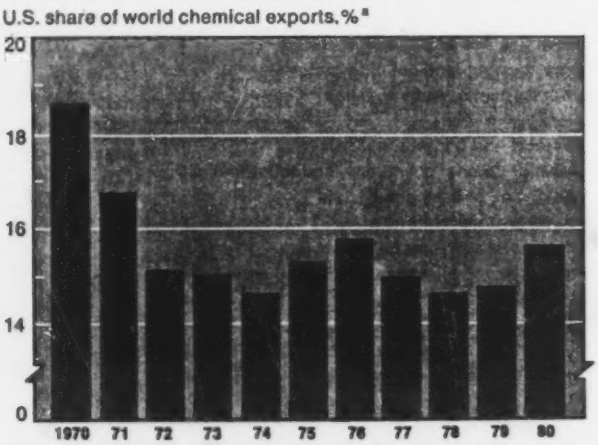
c Exports of domestic merchandise, including Department of Defense and Grant-Aid shipments.
Source: Department of Commerce

U.S. chemical exports maintain rise...



a Running 12-month values for U.S. chemical exports, imports, and trade balance.
Source: Department of Commerce

...and their share of the world market is up



a U.S. exports as a percentage of world chemical exports less U.S. imports.
Source: C&EN estimates based on Department of Commerce and United Nations data

WORLD TRADE: West Germany stays on top

$ Millions	1980	1979	1978	1970
CHEMICAL EXPORTS				
World	$141,000[a]	$125,540[a]	$95,927	$21,880
U.S.	20,740	17,306	12,618	3,826
Canada	3,507	2,897	2,111	566
EC, nine countries[b]	76,183	69,225	52,078	11,427
Belgium-Luxembourg	7,395	6,644	5,701	985
France	13,268	11,646	8,835	1,771
Italy	5,261	5,810	3,710	907
Netherlands	11,299	10,325	7,425	1,517
U.K.	12,306	10,451	8,064	1,887
West Germany	24,304	22,415	18,835	4,093
Switzerland	5,680	5,354	4,804	1,081
Japan	6,767	6,100	5,102	1,234
CHEMICAL IMPORTS				
World	—	—	—	—
U.S.	8,583	7,485	6,427	1,450
Canada	3,127	3,076	2,556	802
EC, nine countries[b]	55,917	50,562	36,682	8,310
Belgium-Luxembourg	5,984	5,376	4,627	827
France	12,179	9,890	7,280	1,527
Italy	7,976	6,992	4,725	1,184
Netherlands	6,383	5,760	4,175	1,048
U.K.	7,025	7,232	5,293	1,303
West Germany	13,308	12,399	8,785	1,881
Switzerland	3,648	3,156	2,421	653
Japan	6,202	5,178	3,763	1,000

a C&EN estimates. b European Communities; historical data have been adjusted to reflect nine countries that were members during 1980 but exclude Greece, which joined in 1981. **Sources:** United Nations, Organization of Economic Cooperation & Development, European Communities, individual country data

U.S. TRADE: Europe is best customer, source

$ Millions	1980	1979	1978	1970
U.S. CHEMICAL EXPORTS				
Canada	$2,134	$ 1,994	$ 1,739	$ 554
Western Europe	6,429	5,585	4,275	1453
Eastern Europe	88	200	62	37
Communist Asia	386	125	61	—
Japan	1,964	1,652	1,104	322
Rest of Asia	2,782	2,204	1,324	335
Middle East	459	387	367	62
Latin America	4,846	3,814	2,679	716
Australasia	645	608	417	114
Africa	721	465	349	122
Other	286	272	241	111
TOTAL	**$20,740**	**$17,306**	**$12,618**	**$3826**
U.S. CHEMICAL IMPORTS				
Canada	$2494	$2362	$1805	$ 362
Western Europe	3953	3449	3227	610
Eastern Europe	195	107	78	8
Communist Asia	107	60	34	—
Japan	697	616	563	176
Rest of Asia	163	148	124	18
Middle East	58	48	41	5
Latin America	536	405	312	55
Australasia	206	158	115	94
Africa	62	49	46	9
Other	112	83	82	113
TOTAL	**$8583**	**$7485**	**$6427**	**$1450**

Source: Department of Commerce

U.S. TRADE BY PRODUCTS: Organics are most important both going and coming

	Chemical exports[a]				Chemical imports[b]			
$ Millions	1980[c]	1979[c]	1978[c]	1970	1980[c]	1979[c]	1978[c]	1970
Organic chemicals	$ 5,697	$ 5,055	$ 3,369	$1133	$2539	$2159	$1734	$ 363
Inorganic chemicals	2,106	1,712	1,207	428	1323	1106	915	371
Radioactive and associated materials	833	937	717	145	989	953	912	32
Dyeing, tanning, and coloring materials	186	177	145	46	194	185	171	77
Pigments, paints, and varnishes	304	273	241	91	89	76	63	9
Medicinals and pharmaceuticals	1,932	1,591	1,404	420	508	441	449	87
Flavors, perfumes, cosmetics, and toiletries	479	399	356	89	301	263	230	72
Cleaning and polishing materials	327	290	250	86	72	73	62	10
Fertilizers, manufactured	2,265	1,404	1,091	178	1104	976	869	192
Explosives and pyrotechnics	87	62	65	20	59	58	43	28
Plastics and resins	3,884	3,241	2,088	653	646	628	518	123
Pesticides and disinfectants	553	516	445	d	263	190	159	d
Miscellaneous chemical products	2,087	1,649	1,240	552	496	379	303	85
TOTAL	**$20,740**	**$17,306**	**$12,618**	**$3826**	**$8583**	**$7485**	**$6427**	**$1450**

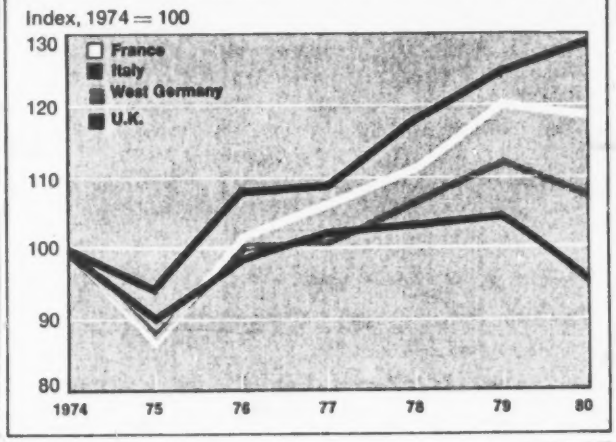
a Exports of domestic merchandise, including Department of Defense and Grant-Aid shipments; FAS (free alongside ship) value. b General imports, FAS value. c As a result of statistical reclassification, data for 1978–80 are not directly comparable to those of previous years; C&EN has rearranged earlier data to make them as comparable as possible. d Included in miscellaneous. **Source:** Department of Commerce

Figures for 1980 point up the difficulties being encountered by chemical producers in Western Europe. Last year, several of the major companies posted net losses, compared to none the previous year. And even the companies that had a profit generally registered marked declines in profit margins.

Output of chemicals was well below 1979 levels throughout most of Western Europe. Plastics and synthetic rubber were among the hardest hit products. Petrochemical raw materials like olefins and aromatics also were weak. And both consumption and output of man-made fibers generally were lower, with the steepest declines showing up in the U.K. One product area that did show some gains was nitrogenous fertilizers, especially in West Germany and the U.K.

Sales volumes of chemicals, on the other hand, were higher throughout the major producing nations of the region, as were exports and imports But credit for that rests largely on the steady increases in the selling prices of most chemical products.

Chemical output generally faltered in 1980



PRODUCTION: Organic chemicals and plastics took a drubbing in 1980

Millions of lb	1980	1979	1978	1977	Change 1979–80
FRANCE					
Sulfuric acid	10,862	10,905	10,096	9,898	0%
Hydrochloric acid	1,473	1,575	1,509	1,481	−7
Phosphoric acid	448	447	373	383	0
Chlorine	2,742	2,829	2,779	2,713	−3
Sodium hydroxide	2,920	3,100	2,948	2,913	−6
Sodium carbonate	3,419	3,410	2,977	2,713	0
Ammonia	4,587	4,730	4,435	4,473	−3
Sodium sulfate	326	334	275	262	−2
Sulfur	4,049	4,268	4,180	4,204	−5
Benzene	1,203	1,392	1,141	1,086	−14
Toluene	136	190	118	155	−28
Xylenes	165	228	244	159	−28
Ethylene	4,437	4,946	4,228	4,107	−10
Propylene	2,119	2,543	2,339	2,070	−17
Phthalic anhydride	171	195	196	191	−12
Methanol	761	777	763	827	−2
Formaldehyde	395	309	277	327	28
Acetone	217	271	268	271	−20
Butadiene	562	659	631	576	−15
Polyethylene	2,333	2,580	2,158	2,097	−10
Polypropylene	462	444	319	198	4
Polystyrene	550	590	449	513	−7
Polyvinyl chloride	1,588	1,722	1,463	1,419	−8
Synthetic rubber	1,113	1,190	1,080	1,054	−7
Phosphate fertilizers (P_2O_5)	2,985	2,872	2,660	2,664	4
U.K.					
Sulfuric acid	7,537	7,696	7,599	7,489	−2%
Hydrochloric acid[a]	315	348	290	308	−9
Chlorine	2,004	2,262	2,112	2,275	−11
Benzene	1,735	2,323	1,947	2,136	−25
Ethylene	2,409	2,715	2,411	2,504	−11
Phthalic anhydride	101	207	200	218	−51
Thermoplastics	3,106[b]	3,659	3,491	3,509	−15
Polyethylene	999	1,069	942	1,074	−7
Polypropylene	429	581	642	546	−26
Polystyrene	363	466	460	504	−22
Polyvinyl chloride	755	957	902	849	−21
Synthetic rubber	473[b]	609	645	704	−22
Nitrogen fertilizers (N)[a]	1,516	1,388	1,313	1,393	9
Phosphate fertilizers (P_2O_5)[a]	759	889	920	990	−15
WEST GERMANY					
Sulfuric acid	8,554	9,082	8,400	8,404	−6%
Chlorine	6,591	7,075	6,624	6,193	−7
Sodium carbonate	3,104	3,080	2,699	2,955	1
Ammonia	4,495	4,754	4,301	4,376	−6
Sodium sulfate	416	458	464	530	−9
Benzene	2,022	2,213	1,967	1,813	−9
Toluene	572	656	497	535	−13
Xylenes	783	1,085	913	997	−28
Ethylene	6,739	7,803	7,093	6,525	−14
Phthalic anhydride	493	587	590	539	−16
Methanol	1,782	1,888	1,771	1,956	−6
Plastics	14,762	15,875	14,835	13,730	−7
Polyethylene	3,080	3,472	3,348	3,155	−11
Polyvinyl chloride	2,097	2,387	2,213	1,973	−12
Synthetic rubber	900	981	926	955	−8
Nitrogen fertilizers	3,252	2,961	2,781	2,867	10
Phosphate fertilizers (P_2O_5)	1,595	1,547	1,553	1,593	3

a Manufacturers' sales. b Estimated. Sources: Union des Industries Chimiques, Chemical Industries Association, Verband der Chemischen Industrie

SYNTHETIC FIBERS: Output fell in most of Western Europe last year

Millions of lb	1980 Non-cellulosics[a]	1980 Cellulosics	1979 Non-cellulosics[a]	1979 Cellulosics	1978 Non-cellulosics[a]	1978 Cellulosics	1977 Non-cellulosics[a]	1977 Cellulosics	1976 Non-cellulosics[a]	1976 Cellulosics	Change, 1979–80 Non-cellulosics	Change, 1979–80 Cellulosics
West Germany	1620	305	1725	295	1649	293	1568	290	1710	305	−6%	3%
Italy	897	143	988	156	952	190	830	235	887	234	−9	−8
U.K.	700[b]	291[c]	838	504	885	472	791	460	911	481	−17	−42
Spain	429	117	466	128	416	133	351	128	327	125	−8	−9
France	422	146	493	169	542	163	532	179	547	186	−14	−14
Benelux countries	212	164	286	165	306	165	295	156	314	151	−26	−1
Switzerland	165	4	185	7	194	9	171	10	172	10	−11	−43
Ireland	92	—	86	—	68	—	35	—	39	—	7	—
Portugal	na	na	68	7	62	5	36	6	26	6	—	—
Austria	56	255	62	242	67	236	57	226	60	228	−10	5

a Excludes polypropylene. b Includes cellulose acetate filament. c Excludes cellulose acetate filament. **Source:** Comité International de la Rayonne et des Fibres Synthétiques

CHEMICAL INDUSTRY TRENDS: Inflation pushes up sales despite lower output

$ Billions	1980	1979	1978	1977	1976
WEST GERMANY					
Sales	$59.2	$56.0	$44.6	$38.1	$33.5
Exports	26.0	24.0	18.4	15.7	13.7
Imports	14.6	13.2	9.5	8.1	6.9
Capital spending	3.8	3.3	2.8	2.4	2.2
Production index (1975 = 100)	122.7	127.9	121.3	115.0	114.6
Price index (1975 = 100)	115.2	106.8	99.2	100.8	101.1
Employees (thousands)	550	547	548	553	556
U.K.[a]					
Sales	$41.0	$35.6	$27.6	$24.1	$20.8
Exports	12.3	10.4	8.1	6.7	5.5
Imports	7.3	7.2	5.3	4.3	3.6
Capital spending	3.2	2.5	2.1	1.4	1.1
Production index (1975 = 100)	109.1	119.2	117.6	116.4	113.3
Price index (1975 = 100)	191.1	165.1	146.7	135.8	117.4
Employees (thousands)	430	441	439	429	423
FRANCE[a]					
Sales	$37.3	$32.9	$24.7	$21.6	$19.3
Exports	13.0	11.5	8.2	6.6	6.2
Imports	10.4	8.9	6.7	5.4	5.5
Capital spending	1.3	1.4	1.1	0.9	0.9
Production index (1975 = 100)	134.4	135.8	125.8	120.5	114.6
Price index (1975 = 100)	159.6	134.1	116.2	111.6	104.6
Employees (thousands)	296	301	306	307	304
ITALY					
Sales	$28.7	$23.7	$17.9	$15.1	$14.4
Exports	5.9	5.2	3.9	3.5	3.1
Imports	9.0	7.9	5.4	4.2	4.0
Capital spending	1.9	1.7	1.3	1.6	1.4
Production index (1975 = 100)	137.5	132.6	125.0	115.4	115.1
Price index (1975 = 100)	195.4	162.0	131.8	125.5	117.3
Employees (thousands)	289	291	292	293	296
BELGIUM AND LUXEMBOURG[a]					
Sales	$16.6	$14.4	$10.0	$8.5	$6.6
Exports	10.4	9.3	7.2	5.7	5.0
Imports	7.5	6.6	5.0	4.4	3.2
Capital spending	0.5	0.5	0.5	0.4	0.5
Production index (1975 = 100)	125.4	133.4	123.4	119.3	112.8
Price index (1975 = 100)	121.1	107.1	104.2	104.2	104.1
Employees (thousands)	90	82	89	92	91

$ Billions	1980	1979	1978	1977	1976
NETHERLANDS					
Sales	$14.3	$13.5	$10.0	$8.5	$7.8
Exports	13.0	11.8	8.6	7.3	6.8
Imports	7.9	7.0	5.1	4.3	4.0
Capital spending	0.7	0.6	0.8	1.0	0.7
Production index (1975 = 100)	130.0	136.0	124.0	119.3	117.7
Price index	125.0	114.0	103.0	104.9	106.4
Employees (thousands)	91	92	94	96	98
SPAIN[a]					
Sales	$17.3	$15.4	$11.1	$9.4	$9.8
Exports	2.5	2.0	1.2	1.0	0.9
Imports	3.5	3.1	2.1	1.9	2.1
Capital spending	0.7	0.6	0.4	0.4	0.5
Production index (1975 = 100)	132.3	135.0	237.0[b]	228.0[b]	208.6[b]
Price index (1975 = 100)	202.0	167.0	226.0[b]	209.0[b]	194.1[b]
Employees (thousands)	244	245	215	215	222
SWITZERLAND[a]					
Sales	$6.8	$6.6	$6.0	$4.3	$4.1
Exports	5.6	5.3	4.7	3.4	3.2
Imports	3.7	3.2	2.4	1.9	1.8
Production index (1975 = 100)	130.5	128.4	123.1	118.8	119.7
Price index (1975 = 100)	97.0	90.7	89.1	93.9	95.2
Employees (thousands)	62	62	62	61	61
SWEDEN					
Sales	$4.3	$3.9	$3.0	$2.8	$2.7
Exports	1.7	1.5	1.2	1.0	0.9
Imports	2.9	2.7	2.0	1.8	1.6
Capital spending	0.4	0.4	0.3	0.3	0.2
Production index (1975 = 100)	106.3	111.3	109.2	102.6	104.3
Price index (1975 = 100)	154.0	134.0	118.0	108.8	103.5
Employees (thousands)	39	40	40	41	40
NORWAY[a]					
Sales	$4.2	$4.1	$3.1	$2.9	$2.5
Exports	1.2	0.9	0.7	0.5	0.5
Imports	1.1	1.0	0.8	0.7	0.6
Capital spending	0.2	0.1	0.3	0.4	0.3
Production index (1975 = 100)	108.0	108.0	99.0	100.6	95.9
Price index (1975 = 100)	131.0	116.0	103.0	100.3	94.2
Employees	35	35	35	31	30

a Excludes fibers. b 1970 = 100. **Sources:** National chemical federations and Conseil Européen des Fédérations de l'Industrie Chimique

COMPANY RESULTS: Sales generally were higher but profits slumped in 1980

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Hoechst (West Germany)						
1980	$16,436.8	$305.5	1.9%	$1053.8	$714.8	187
1979	14,797.8	355.2	2.4	893.4	624.0	183
1978	12,156.3	209.5	1.7	734.2	539.7	181
1977	10,308.8	134.6	1.3	657.1	462.0	181
Bayer (West Germany)						
1980	$15,837.9	$401.1	2.5%	$1461.0	$681.9	182
1979	14,208.7	237.7	1.7	1224.0	603.3	181
1978	11,475.4	234.7	2.0	867.8	513.1	179
1977	9,465.5	150.4	1.6	835.8	410.2	170
BASF (West Germany)						
1980	$15,236.8	$197.3	1.3%	$1011.5	$545.6	117
1979	14,150.8	338.3	2.4	989.6	487.4	117
1978	10,810.5	211.6	2.0	882.9	417.1	115
1977	9,358.4	171.7	1.8	732.3	345.6	114
Imperial Chemical Industries (U.K.)						
1980	$13,290.7	$302.3[a]	2.3%	$1683.7	$493.0	143
1979	11,397.0	970.2	8.5	1613.6	392.8	148
1978	8,700.6	637.2	7.3	1345.5	314.8	151
1977	8,137.9	596.9	7.3	856.9	261.8	154
Montedison (Italy)						
1980	$9,090.0	($523.4)[b]	—	$450.9	$205.6	106
1979	8,222.6	14.4	0.2%	454.9	190.1	115
1978	6,818.2	($317.6)[b]	—	631.6	161.7	127
1977	6,204.1	(523.8)	—	829.2	147.4	135
DSM (Netherlands)						
1980	$7,496.5	$12.6	0.2%	$258.3	$75.4	31
1979	6,343.3	44.3	0.7	266.7	67.2	32
1978	4,631.9	12.0	0.3	464.8	62.5	32
1977	4,136.7	44.9	1.1	575.9	53.1	33
Rhône-Poulenc (France)						
1980	$7,139.2	($ 77.3)[b,c]	—	$611.6	$354.6	95
1979	7,948.5	186.1	2.3%	517.7	305.9	102
1978	5,657.3	52.9	0.9	306.9	244.2	107
1977	4,808.8	17.1	0.4	296.5	211.6	111
Ciba-Geigy (Switzerland)						
1980	$7,134.1	$182.6	2.6%	$510.8	$561.1	81
1979	5,958.4	197.0	3.3	360.2	496.4	80
1978	4,989.9	201.1	4.0	309.5	425.7	75
1977	4,142.1	175.0	4.2	266.7	316.7	74
Akzo (Netherlands)						
1980	$6,257.8	$ 85.4	1.4%	$324.1	$258.8	83
1979	5,977.6	143.8	2.4	229.5	228.9	83
1978	4,938.0	22.7	0.5	200.9	203.7	83
1977	4,258.4	(21.2)[b]	—	166.9	175.5	84

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Solvay (Belgium)						
1980	$4,734.9	$ 67.6	1.4%	$368.0	$154.0	49
1979	4,126.2	175.2	4.3	288.7	98.1	46
1978	3,003.5	102.9	3.4	281.4	83.7	45
1977	2,527.1	74.6	3.0	218.2	67.1	45
Hoffmann-La Roche (Switzerland)						
1980	$3,506.5	$138.9	4.0%	$309.0	$415.0	44
1979	3,127.0	131.9	4.2	318.1	389.2	43
1978	2,706.3	112.2	4.2	226.3	355.9	42
1977	2,286.0	140.0	6.1	252.5	na	40
Sandoz (Switzerland)						
1980	$2,934.1	$121.0	4.1%	$153.9	$248.5	36
1979	2,677.1	104.2	3.9	124.7	232.5	35
1978	2,400.6	87.2	3.6	130.2	211.2	35
1977	1,988.8	89.2	4.5	89.2	168.3	36
BOC International (U.K.)						
1980	$2,777.9	$102.8	3.7%	$312.6	na	45
1979	2,609.3	94.7	3.6	280.7	na	49
1978	2,295.8	68.5	3.0	256.2	na	56
1977	1,170.3	82.2	7.0	126.7	na	41
CdF Chimie (France)						
1980	$2,576.8	($130.0)[b]	—	$ 87.5	$43.7	13
1979	2,346.4	13	0.1%	110.6	23.5	16
1978	1,501.3	(58.2)[b]	—	200.0	20.4	13
1977	981.5	(14.3)[b]	—	139.7	16.7	11
Fisons (U.K.)						
1980	$1,055.1	($ 3.3)[b]	—	$28.1	$32.6	11
1979	919.3	28.1	3.1%	36.3	30.6	13
1978	668.5	36.0	5.4	38.4	25.0	13
1977	511.9	28.6	5.6	31.4	18.7	12
Albright & Wilson (U.K.)						
1980	$986.0	($ 4.0)[b]	—	$70.5	na	9
1979	838.4	36.1	4.3%	69.2	na	10
1978	656.6	44.3	6.7	83.3	na	10
1977	589.9	49.8	8.4	42.8	na	10
UCB (Belgium)						
1980	$786.4	$ 7.5	1.0%	$38.2	$21.9	8
1979	695.4	11.3	1.6	21.0	19.6	8
1978	559.9	1.7	0.3	23.5	18.3	9
1977	477.2	($11.1)[b]	—	22.7	18.6	9
Laporte Industries (U.K.)						
1980	$457.0	$ 7.4	1.6%	$37.2	na	5
1979	403.6	17.4	4.3	34.0	na	5
1978	320.7	10.2	3.2	23.0	na	5
1977	264.4	8.7	3.3	19.2	na	5

a Excludes extraordinary write-off for company restructuring of $348.8 million. b Deficit. c Excludes extraordinary write-off for company restructuring of $383 million. na = not available.

NOTE ON CURRENCY CONVERSION

For monetary statistics in this section, European currencies were converted to U.S. dollars by the following conversion rates:

	$1.00 (U.S.) is equivalent to:									
	Belgium	France	Italy	Netherlands	Norway	Spain	Sweden	Switzerland	U.K.	West Germany
1980	29.24 francs	4.23 francs	856 lire	1.99 guilders	4.94 crowns	71.71 pesetas	4.23 crowns	1.67 francs	0.430 pound	1.82 marks
1979	29.32 francs	4.25 francs	831 lire	2.01 guilders	5.06 crowns	67.12 pesetas	4.29 crowns	1.66 francs	0.471 pound	1.83 marks
1978	31.67 francs	4.50 francs	847 lire	2.16 guilders	5.22 crowns	76.00 pesetas	4.52 crowns	1.79 francs	0.521 pound	1.99 marks
1977	35.84 francs	4.91 francs	882 lire	2.45 guilders	5.33 crowns	76.00 pesetas	4.45 crowns	2.40 francs	0.573 pound	2.26 marks
1976	38.60 francs	4.78 francs	832 lire	2.64 guilders	5.44 crowns	66.90 pesetas	4.34 crowns	2.50 francs	0.554 pound	2.52 marks

Some of the bloom faded from Japan's chemical industry last year—at least for petrochemicals. After two years of strong growth that pushed on into the early months of 1980, petrochemical producers had to face up to some harsh realities during the second half of the year. Growth in production skidded to a halt. Soon output started to decline and several plants had to be shut down.

Production of ethylene, the bellwether of Japan's petrochemical industry, slumped 12% last year. The fortunes of the major derivatives of ethylene were disturbingly similar. In fact, of the 31 organic chemicals and plastics for which data are available, only three were produced in greater volume in 1980 than in 1979, and even for them the increases were 2% or less.

The impact on company profits was predictable. In all but a very few cases, profit margins of the leading Japanese petrochemical companies took a beating during their latest fiscal year.

WORLD TRADE: Chemical trade has surplus

$ Millions	1980	1979	1978	1977
Total exports	$129,807	$103,032	$97,543	$80,495
Total imports	140,528	110,672	79,343	70,809
Chemical exports	6,767	6,100	5,102	4,300
Chemical imports	6,202	5,178	3,763	3,003

Source: Ministry of International Trade & Industry

INDUSTRY TRENDS: Petrochemicals slump

Index, 1975 = 100	1980	1979	1978	1979–80
All chemicals				
Production	144.7	143.7	131.3	1%
Shipments	139.9	143.6	130.0	−3
Inventories	113.5	101.1	100.7	12
Petrochemicals				
Production	133.6	147.9	133.4	−10
Shipments	132.1	147.1	131.6	−10
Inventories	132.6	112.5	109.2	18
Plastics				
Production	149.3	160.4	133.4	−7
Shipments	149.1	161.4	132.4	−8
Inventories	116.2	99.7	91.6	17
Synthetic fibers				
Production	128.7	129.7	129.6	1
Shipments	131.7	136.2	136.9	−3
Inventories	77.1	80.4	95.1	−4
Synthetic rubber				
Production	138.7	140.4	130.4	−1
Shipments	129.7	131.0	122.5	−1
Inventories	125.1	102.0	102.7	23
Fertilizer				
Production	85.5	90.2	89.2	−5
Shipments	93.6	99.7	96.5	−6
Inventories	72.0	72.1	76.3	0
All manufacturing				
Production	142.8	133.3	123.0	7
Shipments	137.1	130.7	121.4	5
Inventories	110.4	102.6	103.0	8

Source: Ministry of International Trade & Industry

PRODUCTION: Plastics and organics down

Thousands of metric tons unless otherwise indicated	1980	1979	1978	1977	Change 1979–80
ORGANIC CHEMICALS					
Acetaldehyde	432	583	587	624	−26%
Acetic acid	418	502	518	544	−17
Acetone	235	254	261	238	−7
Acrylonitrile	469	579	609	596	−19
Benzene	2060	2178	2015	1951	−5
Butadiene	574	658	658	610	−13
Butyl alcohol	222	252	222	194	−12
Caprolactam	443	437	427	453	1
Cyclohexane	500	509	477	515	−2
Dioctylphthalate	241	259	268	236	−7
Ethylene	4176	4755	4387	3979	−12
Ethylene dichloride	2060	2110	1837	1723	−2
Ethylene glycol	492	572	630	523	−14
Ethylene oxide	529	593	631	538	−11
Methanol	836	940	907	762	−11
Octyl alcohol, synthetic	241	264	254	212	−9
Phenol, synthetic	215	244	249	221	−12
Phthalic anhydride	235	284	288	260	−17
Propylene	2644	3096	2963	2716	−15
Propylene glycol	163	168	163	141	−3
Styrene	1114	1238	1122	1022	−10
Terephthalic acid	601	613	590	433	−2
Toluene	889	925	861	869	−4
Toluene diisocyanate	67	66	61	65	2
Xylene	1195	1317	1248	1211	−9
Urea	1770	2083	2079	1718	−15
INORGANIC CHEMICALS					
Ammonium chloride	683	753	718	709	−9
Ammonium sulfate	1879	1883	1929	2048	0
Calcium carbide	550	570	555	541	−4
Calcium superphosphate	591	568	551	607	4
Carbon black	575	538	489	439	7
Chlorine, liquid	763	729	651	689	5
Hydrochloric acid	570	528	540	616	8
Nitrogen, millions of cu m	4586	4150	3717	3941	11
Oxygen, millions of cu m	6854	7070	6329	6773	−3
Sodium carbonate	1357	1355	1162	1179	0
Sodium hydroxide	3159	3021	2777	2870	5
Sodium silicate	712	714	654	632	0
Sulfuric acid	6777	6581	6435	6392	3
Titanium dioxide	173	185	171	150	−7
PLASTICS					
Phenolic resins	304	300	268	246	1
Polyethylene	1860	2165	1767	1467	−14
Polypropylene	927	1023	745	608	−9
Polystyrene	1129	1227	1032	900	−8
Polyvinyl chloride	1429	1583	1204	1030	−10
DYES, synthetic	51	60	54	54	−15
RUBBER CHEMICALS, organic	46	45	41	36	2
RUBBER, synthetic	1094	1107	1028	971	−1

Source: Ministry of International Trade & Industry

COMPANY RESULTS: Profitability slips for many Japanese chemical firms

$ Millions	Sales	Net income	Profit margin	Total assets	Employees (thousands)
Mitsubishi Chemical Industries[a]					
1980	$3760	$42.3	1.1%	$3739	8.0
1979	2742	25.5	0.9	2996	8.2
1978	2458	11.0	0.5	3535	8.7
1977	2451	22.7	0.9	3319	9.0
Sumitomo Chemical[b]					
1980	$3196	$47.0	1.5%	$2856	9.7
1979	2202	45.0	2.0	2017	9.9
1978	2078	18.6	0.9	2532	10.8
1977	2007	6.0	0.3	2601	11.6
Asahi Chemical Industry					
1980	$2938	$67.7	2.3%	$2825	13.6
1979	2168	47.2	2.2	2266	13.8
1978	2029	33.9	1.6	2476	14.3
1977	1980	21.9	1.1	2402	15.7
Toray Industries					
1980	$2538	$54.1	2.1%	$2408	13.8
1979	1924	55.7	2.9	2010	13.9
1978	1929	40.3	2.1	2271	14.7
1977	1828	4.3	0.0	2117	16.9
Teijin					
1980	$2115	$28.2	1.3%	$2093	7.3
1979	1613	28.8	1.8	1815	7.2
1978	1611	10.7	0.7	2016	7.7
1977	1553	1.8	0.1	1977	8.1
Mitsui Toatso Chemicals					
1980	$2115	$23.5	1.1%	$1941	7.7
1979	1624	36.3	2.2	1613	7.8
1978	1455	5.4	0.4	1773	8.3
1977	1388	(19.7)[c]	—	1762	8.9
Showa Denko[b]					
1980	$2077	$32.9	1.6%	$2276	5.5
1979	1496	27.3	1.8	1475	4.3
1978	1339	17.6	1.3	1850	5.2
1977	1672	(8.6)[c]	—	2192	6.3
Mitsubishi Petrochemical[b]					
1980	$1904	$16.5	0.9%	$1908	3.8
1979	1366	16.5	1.2	1384	3.9
1978	1213	8.8	0.7	1607	4.3
1977	1203	3.7	0.3	1586	4.5
Dainippon Ink & Chemicals					
1980	$1692	$22.1	1.3%	$1448	5.8
1979	1301	18.4	1.4	1124	5.5
1978	1248	19.4	1.6	1084	5.5
1977	1081	16.7	1.6	979	5.5
Sekisui Chemical					
1980	$1504	$20.2	1.3%	$1359	6.1
1979	1195	17.3	1.5	1107	6.0
1978	1128	7.4	0.7	1025	5.9
1977	955	4.7	0.5	855	6.2
Mitsui Petrochemical Industries					
1980	$1424	$21.2	1.5%	$1474	4.6
1979	1167	23.2	2.0	1127	4.8
1978	914	11.0	1.2	1221	4.8
1977	864	7.9	0.9	1186	4.7
Unitika					
1980	$1043	$ 6.1	0.6%	$1229	6.3
1979	785	2.3	0.3	1024	6.5
1978	865	12.0	1.4	1246	6.8
1977	827	(39.7)[c]	—	1295	8.3
Toyo Soda Mfg.					
1980	$1011	$ 9.4	0.9%	$1251	5.0
1979	809	14.5	1.8	977	4.9
1978	721	10.5	1.5	1075	5.0
1977	674	3.5	0.5	1043	5.2
Kyowa Hakko Kogyo[b]					
1980	$964	$15.6	1.6%	$749	5.0
1979	694	12.1	1.7	585	4.8
1978	692	13.1	1.9	659	4.8
1977	661	11.5	1.7	624	4.7
Kuraray					
1980	$942	$ 7.1	0.8%	$985	5.7
1979	762	2.7	0.4	824	5.2
1978	790	1.0	0.1	920	5.4
1977	741	(14.4)[c]	—	956	6.3
Mitsubishi Gas Chemical					
1980	$938	$28.7	3.1%	$948	3.8
1979	714	19.7	2.8	740	3.8
1978	604	10.9	1.8	824	3.8
1977	545	8.0	1.5	767	3.9
Denki Kagaku Kogyo					
1980	$931	$15.0	1.6%	$1078	4.0
1979	761	17.1	2.3	881	4.0
1978	691	9.6	1.4	942	4.1
1977	637	6.1	1.0	895	4.2
Mitsubishi Rayon					
1980	$893	$12.2	1.4%	$814	3.5
1979	676	23.6	3.5	703	3.4
1978	701	(5.1)[c]	—	808	3.7
1977	800	(6.0)[c]	—	919	4.8
Kanegafuchi Chemical Industry					
1980	$823	$14.1	1.7%	$612	3.1
1979	661	16.0	2.4	466	3.0
1978	616	7.9	1.3	534	3.0
1977	555	(2.4)[c]	—	544	3.1
Japan Synthetic Rubber					
1980	$776	$ 8.9	1.1%	$761	2.6
1979	542	12.6	2.3	579	2.6
1978	514	6.6	1.3	595	2.7
1977	467	4.4	0.9	584	2.7
Tokuyama Soda					
1980	$776	$5.2	0.7%	$682	2.4
1979	616	5.8	0.9	546	2.4
1978	568	6.5	1.1	606	2.4
1977	524	5.3	1.0	593	2.4
Hitachi Chemical					
1980	$766	$9.4	1.2%	$440	4.3
1979	596	8.6	1.4	336	4.1
1978	602	6.6	1.1	365	4.0
1977	522	(2.9)[c]	—	356	4.0
Daicel Chemical					
1980	$705	$15.0	2.1%	$659	3.1
1979	501	15.7	3.1	467	3.1
1978	467	8.6	1.8	461	3.4
1977	453	6.5	1.4	425	3.4
Nissan Chemical Industry[d]					
1980	$682	$3.5	0.5%	$603	1.8
1979	537	3.3	0.6	476	1.8
1978	483	3.1	0.6	554	1.8
1977	438	1.4	0.3	520	2.2

a Fiscal year starts Jan. 31. b Fiscal year starts Dec. 31. c Deficit. d Fiscal year starts April 30. **Note:** Fiscal years starting March 31 of each year unless otherwise specified. Fiscal year 1979 are estimates based on results for the first three quarters. Results were converted from yen on the following basis: fiscal year 1980—$1.00 = 212.9 Y; fiscal year 1979—$1.00 = 249.4 Y; fiscal year 1978—$1.00 = 209.3 Y; fiscal year 1977—$1.00 = 222.9 Y. Year-to-year changes in sales and net income are affected by fluctuations in the exchange rate. **Source:** Toyo Keizai Shinposha.

Last year brought further expansion for Canada's natural-gas-based petrochemical industry.

With Alberta Gas Ethylene's 1.2 billion lb-a-year ethylene plant at Red Deer, Alta., operating for its first full year, Canadian ethylene production increased a hefty 17% in 1980 to almost 1.2 million metric tons. Although some ethylene derivatives didn't fare too well—output of polystyrene was down 11% and polyethylene was up only 2%—others scored significant gains. Polyvinyl chloride production, for example, increased 27%.

A large share of these ethylene derivatives are exported and helped contribute to Canada's $636 million surplus in chemical foreign trade in 1980. The country's petrochemical industry seems to be well on its way to achieving its goals for the 1980's: to build economical world-scale plants, satisfy domestic demand, and find export markets for its surplus production.

TRADE BALANCE: Surplus widens overall. . .

$ Millions (Canadian)	1980	1979	1978	1977
Exports[a,b]	$73,821	$64,190	$52,842	$44,554
Imports[c]	68,710	62,724	49,938	42,332
Trade balance	5,111	1,466	2,904	2,222

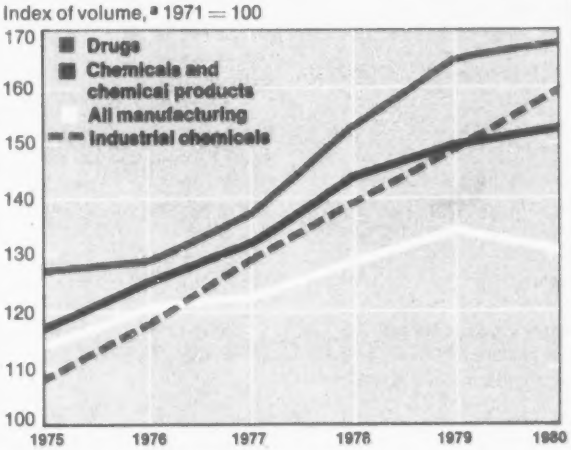
. . . with the help of chemical exports

$ Millions (Canadian)	1980	1979	1978	1977
Chemical exports[b,d]	$3,975	$3,321	$2,357	$1,739
Chemical imports	3,339	3,234	2,621	1,992
Chemical trade balance	636	87	−264	−253

a Includes re-exports. b Values as declared on export documents; may include shipping costs. c Values as established for duty purposes. d Domestic exports only. **Source:** Statistics Canada

Chemical output bucks overall downturn

Index of volume,[a] 1971 = 100



a Real domestic product. **Source:** Statistics Canada

COMPANY RESULTS: Profits generally higher

$ Millions (Canadian)[a]	Sales	Net income[b]	Profit margin	Capital expenditures	Employees (thousands)
C-I-L INC.[c]					
1980	$1004.2	$51.5	5.1%	$70.2	8.3
1979	880.0	36.3	4.1	84.4	8.0
1978	746.9	26.4	3.5	97.5	8.0
1977	667.8	24.9	3.7	58.5	8.3
CELANESE CANADA					
1980	$391.6	$22.0	5.6%	$15.9	4.2
1979	353.6	21.2	6.0	24.4	4.4
1978	290.7	7.4	2.4	18.2	4.6
1977	254.7	1.1	0.4	5.7	4.7
DOW CHEMICAL CANADA[d]					
1980	$751.0	$59[e]	8.1%	$113	4.0
1979	629.7	50[e]	7.9[e]	292	3.8
1978	438.5	27.6[e]	6.3[e]	250.4	3.3
1977	396.4	46.0[e]	11.6[e]	210.3	3.0
DU PONT CANADA					
1980	$995.3	$42.6	4.3%	$53.2	5.9
1979	879.6	58.9	6.7	23.3	5.6
1978	661.9	10.2	1.5	10.7	5.4
1977	537.6	7.6	1.4	16.7	5.5
UNION CARBIDE CANADA					
1980	$794.8	$79.6	10.0%	$58.9	5.0
1979	685.9	57.8	8.4	30.1	4.8
1978	528.2	20.1	3.8	46.3	4.7
1977	406.5	20.5	5.0	82.3	4.7

a Unless otherwise indicated. b Excluding extraordinary gains and losses. c Name changed from Canadian Industries Ltd. on Jan. 1, 1980. d Amounts in U.S. dollars. e Before taxes.

PRODUCTION: Many big gains, few losses

Thousands of metric tons, unless otherwise noted	1980	1979	1978	1977	Change 1979–80
Ammonia, anhydrous	2555.6	2405.3	2642.9	2383.0	6%
Ammonium nitrate	873.3	914.5	959.9	1019.4	−5
Ammonium phosphate	1466.2	1335.7	1299.5	1264.7	10
Benzene[a]	5486.8	4479.4	3491.3	2741.1	22
Caustic soda, 100% NaOH	1459.2	1138.3	1142.2	1117.5	28
Chlorine	1302.7	1031.4	1037.0	979.2	26
Ethylene	1183.9	1013.8	910.2	625.3	17
Hydrochloric acid	176.8	154.4	170.4	150.2	15
Phosphoric acid, 100% P_2O_5	807.9	747.7	610.5	612.5	8
Polyesters, unsaturated	27.4	32.0	20.3	20.9	−14
Polyethylene	641.7	628.2	477.5	345.1	2
Polystyrene	109.8	123.8	98.8	90.5	−11
Polyvinyl chloride	190.4	149.4	124.7	99.7	27
Sodium chlorate	244.6	223.8	219.5	178.1	9
Sulfuric acid, 100%	4295.4	3666.1	3594.5	3461.6	17
Urea	1274.3	1211.7	1341.7	887.0	5

a Thousands of bbl. **Source:** Statistics Canada

SHIPMENTS: Chemicals' growth is better than average but doesn't match petroleum in Canada

$ Millions (Canadian)	Shipments, monthly average 1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Average annual change 1979–80	1970–80
All manufacturing	$13,798.2	$12,520.7	$10,743.7	$9070.6	$8190.4	$7371.6	$6871.2	$5563.1	$4687.2	$4189.5	$3865.2	10.2%	13.6%
Chemicals and chemical products	893.2	791.9	663.3	535.6	475.3	425.6	383.9	291.9	246.2	231.8	218.3	12.3	14.9
Petroleum and coal products	1,237.6	1,003.0	837.9	711.0	576.8	496.1	432.1	256.1	203.4	176.2	151.6	23.4	23.4
Rubber and plastics products	326.8	300.3	250.1	211.0	192.7	162.9	152.8	131.4	109.7	97.0	89.4	8.8	13.8
Paper and allied products	1,201.6	1,032.0	839.5	744.8	685.7	594.2	639.7	439.2	367.8	333.4	327.6	16.4	13.9

Source: Statistics Canada

PRICES: Double-digit increases for the second year in chemicals

Industry selling price indexes, 1971 = 100	Annual average 1980	1979	1978	1977	1976	1975	1974	1973	1972	Annual change 1979–80	1975–80
All manufacturing industries	247.0	217.8	190.4	174.3	161.6	153.7	138.1	116.1	104.4	13.4%	9.9%
Chemicals and chemical products	251.2	214.8	189.3	175.9	167.2	160.3	137.1	106.5	101.4	16.9	9.4
Industrial chemicals—inorganic	274.0	234.1	204.1	188.4	179.7	169.5	133.5	107.7	102.5	17.0	10.1
Acetylene, compressed	232.9	213.2	191.2	170.7	163.7	150.6	116.2	102.9	102.0	9.2	9.1
Caustic soda	270.0	240.1	221.4	210.7	195.7	169.5	120.2	107.0	103.3	12.5	9.8
Chlorine	243.9	207.9	189.2	180.5	163.3	144.4	114.1	104.3	102.2	17.3	11.0
Oxygen, gas and liquid	202.4	191.8	174.6	156.8	152.1	136.0	121.2	108.3	102.6	5.5	8.3
Industrial chemicals—organic	354.7	289.0	249.8	228.1	214.2	201.2	170.0	107.8	101.6	22.7	12.0
Plastics and synthetic resins	274.4	239.7	206.4	193.3	187.4	181.6	156.0	104.2	100.1	14.5	8.6
Alkyd	176.9	158.4	137.5	129.4	131.4	135.1	134.8	109.4	101.1	11.7	5.5
Phenol formaldehyde	332.8	300.9	233.6	232.1	235.6	240.9	214.1	111.4	98.2	10.6	6.7
Polyethylene	315.3	268.9	223.2	220.3	221.6	213.2	166.3	103.2	98.8	17.3	8.1
Fertilizers, mixed	280.3	229.1	191.0	180.2	176.9	204.0	167.5	117.2	102.5	22.3	6.6
Drugs	169.2	153.1	140.4	131.4	127.0	121.1	109.9	103.5	100.0	10.5	6.9
Paint and varnish	239.8	202.3	183.0	172.8	161.9	153.9	131.9	108.2	101.7	18.5	9.3
Pigments and dry colors	259.8	219.6	189.7	175.3	164.9	153.4	136.0	103.7	96.6	18.3	11.1
Soaps and cleansing compounds	188.8	169.5	151.2	141.1	134.5	132.1	118.0	105.3	101.2	11.4	7.4

Source: Statistics Canada

CHEMICAL IMPORTS: Slow growth in 1980

$ Millions (Canadian)[a]	1980	1979	1978	Change 1979–80
Inorganic chemicals	$ 345.6	$ 351.6	$ 282.3	−2%
Organic chemicals	923.7	887.5	682.0	4
Fertilizers and fertilizer materials	135.1	136.0	94.6	−1
Synthetic and reclaimed rubber	127.8	118.2	93.9	8
Plastics materials, not shaped	532.9	554.8	483.7	−4
Plastic film and sheet	191.3	181.1	152.9	6
Other plastics basic shapes and forms	128.3	134.2	110.9	−4
Dyes, except dyeing intermediates	79.8	81.6	76.2	−2
Pigments, lakes, and toners	53.1	61.8	49.0	−14
Paints and related products	86.1	94.9	82.8	−9
Other chemical products	735.5	611.2	512.5	20
TOTAL	$3339.2	$3212.8	$2620.9	4%

a Values as established for duty purposes. **Source:** Statistics Canada

CHEMICAL EXPORTS: Fertilizers lead

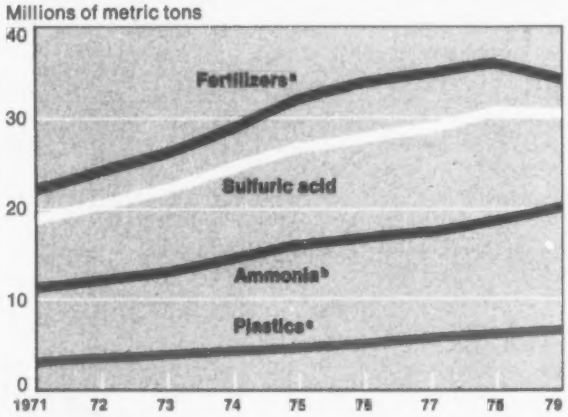
$ Millions (Canadian)[a]	1980	1979	1978	Change 1979–80
Chemical elements	$ 158.8	$ 146.0	$ 124.8	9%
Other inorganic chemicals	875.3	839.5	653.6	4
Organic chemicals	924.2	702.5	401.5	32
Fertilizers and fertilizer materials	1247.3	983.8	734.9	27
Synthetic rubber and plastic materials	467.5	366.9	261.6	23
Plastics basic shapes and forms	123.1	119.2	84.0	3
Other chemical products	178.9	157.3	96.3	14
TOTAL	$3975.1	$3315.2	$2356.7	20%

a Domestic exports only. Values as declared on export documents; may include shipping costs.
Source: Statistics Canada

Economic development in Eastern Europe, including the chemical industry, generally continued in 1980 at the slower pace set in 1979 and 1978, again falling short of plans. Industrial output for the U.S.S.R. and its six East European allies was up only 3.3% in 1980 (the target was 4.7%), compared to 3.7% in 1979, 5.1% in 1978, and 6.0% in 1977.

Soviet chemical and rubber output rebounded in 1980 to the 6.0% growth level of 1978, up from only 2.6% in 1979—the lowest annual increase since World War II. But 1980 production still fell far short of the ambitious 9.0% growth target. Fertilizer output grew to 104 million metric tons, below the 115.3 million target.

Growth slows for Eastern Europe's chemical output



a As N, P_2O_5, and K_2O. b Nitrogen content. c Including resins for man-made fibers in U.S.S.R. **Note:** Data for U.S.S.R., Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania. **Source:** Central Intelligence Agency

PRODUCTION GROWTH: Slower last year

% annual change in gross output	1980	1979	1978	1977	1976
U.S.S.R. and East Europe					
All industry	3.3%	3.7%	5.1%	6.0%	5.5%
Bulgaria					
All industry	4.0	5.4	6.9	6.8	6.8
Chemicals and rubber	8.9	9.1	10.0	12.4	4.9
Czechoslovakia					
All industry	3.2	3.7	4.8	5.7	5.5
Chemicals and rubber[a]	2.7	2.9	5.9	6.7	9.0
East Germany					
All industry[b]	4.7	4.8	3.7	5.4	5.9
Chemicals and rubber	na	4.0	6.0	4.3	6.7
Hungary					
All industry	−2.1	3.0	4.9	6.6	4.6
Chemicals and rubber	−0.1	6.1	10.7	6.9	10.8
Poland					
All industry	−1.3[c]	2.7	4.9	6.9	9.3
Chemicals and rubber	6.1[c,d]	2.3	3.9	4.4	10.8
Romania					
All industry	6.5	8.0	9.6	12.5	11.4
Chemicals and rubber	6.7	1.4	10.6	13.9	16.1
U.S.S.R.					
All industry[e]	3.6	3.4	4.8	5.7	4.8
Chemicals and rubber[e]	6.0	2.6	6.0	6.5	7.9
All industry[f]	na	2.2	3.8	4.1	4.1
Chemicals and rubber[f]	na	−1.4	3.1	5.8	4.8

a Including oil refining. b Industrial commodity production. c Sales. d Results for 10 months. e Figures based on official Soviet statistics. f Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. na = not available. **Sources:** United Nations Economic Commission for Europe, based on official national statistics, Central Intelligence Agency

MAN-MADE FIBERS: Growth modest in 1981

Production, millions of lb	1980	1979	1978	1977	Change 1979–80
NONCELLULOSIC FIBERS[a]					
Bulgaria	na	106	102	97	na
Czechoslovakia	191	159	163	152	20%
East Germany	na	292	281	273	na
Hungary	42	40	41	36	5
Poland	349	338	335	323	3
Romania	na	309	287	273	na
U.S.S.R	1080	1049	1047	1005	3
TOTAL	**na**	**2293**	**2256**	**2159**	**na**
CELLULOSIC FIBERS					
Bulgaria	na	73	68	63	na
Czechoslovakia	121	148	156	160	−18%
East Germany	na	364	360	368	na
Hungary	20	19	20	20	5
Poland	195	185	206	211	5
Romania	na	143	138	131	na
U.S.S.R.	1430	1400	1400	1387	2
TOTAL	**na**	**2332**	**2348**	**2340**	**na**

a Excluding olefins and textile glass. na = not available. **Source:** Textile Economics Bureau

AGRICULTURAL CHEMICALS: U.S.S.R. dominates in Eastern Europe

Thousands of metric tons	1980	1979	1978	1977	1976
Bulgaria					
Fertilizer supply[a]	na	820	738	742	658
Pesticide supply	na	34.8	35.3	26.3	23.4
Czechoslovakia					
Fertilizer supply[a]	1,730	1,745	1,748	1,633	1,674
East Germany					
Fertilizer supply[a]	na	1,713	1,670	1,670	1,804
Pesticide supply	na	26.7	25.3	24.5	23.7
Hungary					
Fertilizer supply[a]	na	1,502	1,539	1,511	1,388
Poland					
Fertilizer supply[a]	na	3,567	3,606	3,586	3,671
Pesticide supply	na	44.4	49.8	57.1	51.1
Romania					
Fertilizer supply[a]	1,217	1,431	1,480	1,128	1,144
U.S.S.R.					
Fertilizer supply[a]	18,589	17,365	18,420	18,034	17,739
Pesticide supply	512	na	na	na	na

a Nutrient content. na = not available. **Source:** United Nations Economic Commission for Europe, based on official national statistics

PRODUCTION: Fertilizers and related chemicals are big-volume products

Thousands of metric tons, unless otherwise noted	1980[a]	1979	1978	1977	1976
U.S.S.R.					
Sulfuric acid, 100%	23,000	22,364	22,411	21,104	20,015
Mineral fertilizers (gross weight)	104,000	94,500	98,000	96,800	92,200
Mineral fertilizers[b]	na	22,140	23,653	23,493	22,590
Nitrogen[b]	na	9,170	9,299	9,114	8,609
Phosphate[b,c]	na	6,315	6,153	6,024	5,664
Potassium[b]	na	6,650	8,197	8,347	8,310
Synthetic ammonia[d]	na	12,750	11,462	10,744	10,090
Sodium carbonate, 100%	na	4,782	4,858	4,876	4,842
Plastics[e]	3,600	3,477	3,516	3,309	3,058
Sodium hydroxide, 100%	2,800	2,680	2,763	2,658	2,604
Synthetic rubber[f]	na	1,867	1,795	1,700	1,570
Rubber tires[g] (thousands of units)	60,100	60,000	59,018	57,400	54,515
Pesticides	471	475	492	487	466
BULGARIA					
Sulfuric acid, 100%	na	998	974	860	857
Mineral fertilizers[b]	na	959	968	984	905
Nitrogen[b]	730	677	685	705	663
Phosphate[b]	na	282	283	279	242
Synthetic ammonia[d]	na	951	960	995	920
Plastics	275	200	178	169	157
Sodium hydroxide, 100%	106	107	102	96	87
Synthetic rubber	na	30	25	25	21
Rubber tires[g] (thousands of units)	na	1,752	1,734	1,830	1,738
CZECHOSLOVAKIA					
Sulfuric acid, 100%	na	1,253	1,195	1,276	1,240
Mineral fertilizers[b]	na	1,140	1,176	1,178	1,100
Nitrogen[b]	na	591	625	605	568
Phosphate[b,c]	na	358	367	389	376
Potassium[b,h]	na	191	191	184	184
Synthetic ammonia[d]	na	768	812	791	725
Plastics	na	853	810	738	581
Sodium hydroxide, 100%	na	302	311	312	293
Synthetic rubber	na	60	59	59	57
Rubber tires[g] (thousands of units)	na	6,520	6,439	6,341	5,983
EAST GERMANY					
Sulfuric acid, 100%	na	990	971	927	957
Mineral fertilizers[b]	na	4,740	4,628	4,470	4,369
Nitrogen[b]	967	900	892	838	776
Phosphate[b,c]	na	444	413	403	423
Potassium[b]	na	3,396	3,323	3,229	3,161
Synthetic ammonia[d]	na	1,147	1,137	1,130	1,119
Plastics	na	790	762	734	679
Sodium hydroxide, 100%	na	415	415	423	441
Synthetic rubber	na	150	145	147	145
Rubber tires[g] (thousands of units)	na	6,805	6,728	6,652	6,432
HUNGARY					
Sulfuric acid, 100%	na	630	690	678	653
Mineral fertilizers[b]	na	850	855	788	767
Nitrogen[b]	na	549	534	514	492
Phosphate[b]	na	165	185	165	188
Potassium[b,h]	na	136	136	109	87
Synthetic ammonia[d]	na	767	746	729	703
Plastics	na	294	213	148	141
Sodium hydroxide, 100%[i]	na	194	146	97	91
Rubber tires[g] (thousands of units)	na	781	773	814	834
POLAND					
Sulfuric acid, 100%	na	2,982	3,172	3,268	3,179
Mineral fertilizers[b]	2,251	2,431	2,621	2,610	2,593
Nitrogen[b]	na	1,375	1,470	1,521	1,548
Phosphate[b]	na	932	1,026	966	928
Potassium[b,h]	na	124	125	123	120
Synthetic ammonia[d]	na	1,513	1,616	1,665	1,726
Plastics	na	441	467	463	446
Sodium hydroxide, 100%	na	436	469	440	388
Synthetic rubber	na	130	126	119	117
Rubber tires[g] (thousands of units)	na	8,500	7,852	7,457	7,207
ROMANIA					
Sulfuric acid, 100%	na	1,765	1,655	1,523	1,555
Mineral fertilizers[b]	2,451	2,522	2,461	1,981	1,869
Nitrogen[b]	na	1,766	1,723	1,381	1,331
Phosphate[b]	na	676	660	548	493
Potassium[b,h]	na	80	78	52	45
Synthetic ammonia[d]	na	2,315	2,259	1,793	1,660
Plastics	na	516	552	543	465
Sodium hydroxide, 100%	na	725	725	735	673
Synthetic rubber	na	149	148	136	95
Rubber tires[g] (thousands of units)	5,105	4,736	4,690	4,372	4,194

a Approximate figures. b Nutrient content basis, as N, P_2O_5, or K_2O. c Including production of ground phosphate rock for direct applications and phosphate animal feeds. d Nitrogen content. e Including resins for man-made fibers. f Estimated. g For all motor vehicle tires, excluding aircraft and bicycle tires. h Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. i Including regenerated NaOH. na = not available. **Sources:** Central Intelligence Agency, Department of Commerce, United Nations Economic Commission for Europe (based on official national statistics)

SOVIET FOREIGN TRADE: Overall balance widens but chemical deficit gets deeper

$ Millions	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
Exports[a]	76,470	64,913	52,395	45,227	37,269	33,401	27,374	21,332	15,409	13,792	12,787
Imports[a]	68,477	57,961	50,795	40,926	38,212	37,070	24,861	20,980	16,104	12,467	11,720
Trade balance	7,993	6,952	1,600	4,301	−943	−3,669	2,513	352	−695	1,325	1,067
Chemical exports[a]	na	1,600	1,284	1,063	939	1,027	887	549	439	396	364
Chemical imports[a]	na	2,800	2,188	1,850	1,668	1,747	1,448	954	868	702	618
Chemical trade balance	na	−1,200	−904	−787	−729	−720	−561	−405	−429	−306	−254

a Free on board na = not available. **Sources:** Central Intelligence Agency, Department of Commerce, based on official Soviet statistics

CHINA

FOREIGN TRADE: Total surged in 1980 . . .

$ Millions	1980[a]	1979	1978	1977	1976
Exports[b]	$19,300	$13,751	$10,118	$8101	$7268
Imports[c]	20,500	15,558	11,187	7121	6022
Trade balance	−1,200	−1,807	−1,069	980	1246

. . . with chemicals also rising in recent years

$ Millions	1979	1978	1977	1976
Chemical exports[b,d]	$ 800	$ 475	$ 410	$ 330
Medicinal products	115	75	60	40
Essential oils and soap	85	60	60	45
Chemical imports[b,d]	1,390	1,085	835	560
Fertilizers	615	430	320	215
Elements and compounds	385	355	270	210
Plastic materials	150	130	90	90
Dyeing materials	80	60	40	20
Chemical trade balance	−590	−610	−425	−230

a Estimated. b Free on board. c Includes cost, insurance, and freight. d Estimated from data reported by China's trading partners. **Source:** Central Intelligence Agency

PRODUCTION: Further growth last year

Thousands of metric tons unless otherwise noted	1980	1979	1978	1977	Change 1979–80
Ammonia[a]	na	10,727	9287	7734	na
Fertilizer[b]	12,320	10,654	8693	7238	16%
Nitrogen (N)	9,990	8,821	7637	6360	13
Phosphate (P_2O_5)	2,310	1,817	1033	860	27
Potash (K_2O)	20	16	21	18	25
Sulfuric acid	7,640	7,000	6610	5375	9
Sodium hydroxide	1,923	1,826	1640	1386	5
Sodium carbonate	1,613	1,486	1329	1077	9
Calcium carbide	1,520	1,407	1237	na	8
Plastics	898	793	679	524	13
Insecticides	537	537	533	457	0
Ethylene	490	435	380	303	13
Synthetic detergents	393	397	324	257	−1
Man-made fibers	450	326	285	190	38
Pharmaceuticals	40	42	41	35	−4
Rubber tires (thousands of units)	11,460	11,690	9359	na	−2

a Nitrogen content of ammonia produced for fertilizer. b Nutrient content. na = not available. **Sources:** State Statistical Bureau of the People's Republic of China, Central Intelligence Agency

TAIWAN

INDUSTRY TRENDS: Chemical growth strong

Industrial production indexes, 1976 = 100	1980	1979	1978	1977	Change 1979–80
All manufacturing	165.2	153.7	142.6	112.9	7%
Chemical materials	201.2	189.1	165.3	129.1	6
Basic chemicals	150.2	148.5	126.1	109.6	1
Petrochemicals	254.4	242.0	194.1	139.8	5
Fertilizers	134.6	127.9	125.9	105.0	5
Synthetic fibers	187.7	174.5	159.7	127.7	8
Plastics and resins	214.5	197.5	176.6	138.4	9
Chemical products	163.9	150.1	132.3	111.4	9
Paints and lacquer	230.9	168.9	141.1	114.9	37
Medicines	130.0	142.9	129.1	113.2	−9
Pesticides	151.1	121.8	121.6	99.3	24
Soaps and detergents	167.8	162.4	137.5	111.1	3

Source: Council for Economic Planning & Development, Taiwan

PRODUCTION: Sulfuric acid is top chemical

Thousands of metric tons	1980	1979	1978	1977	Change 1979–80
Sulfuric acid	769	777	685	541	−1%
Synthetic fibers	587	540	434	341	9
Ammonium sulfate	539	556	541	492	−3
Ammonia	504	476	534	396	6
Ethylene	458	445	366	295	3
Polyvinyl chloride	454	407	389	297	12
Sodium hydroxide	400	420	362	301	−5
Urea	343	312	366	200	10
Xylene	311	285	131	54	9
Synthetic detergents	104	105	86	69	−1
Sodium carbonate	93	81	77	80	15
Calcium carbide	81	83	80	72	−2

Source: Council for Economic Planning & Development, Taiwan

SOUTH KOREA

INDUSTRY TRENDS: Slowdown last year

Industrial production indexes, 1975 = 100	1980	1979	1978	1977	Change 1979–80
All manufacturing	215.9	220.1	196.4	158.7	−2%
Chemicals, petroleum, coal, rubber and plastic products	219.0	219.7	191.6	157.2	0
Industrial chemicals	207.0	200.8	179.6	146.5	3
Other chemical products	240.6	260.9	220.2	172.2	−8
Petroleum refineries	152.5	154.4	142.9	130.2	−1
Rubber products	273.1	244.0	206.0	169.5	12
Plastic products	229.6	293.7	319.9	225.3	−22

Source: Korean Bureau of Statistics

PRODUCTION: Fertilizer output declines

Thousands of metric tons, unless otherwise noted	1980	1979	1978	1977	Change 1979–80
Sulfuric acid	1,683	1,645	1461	1034	2%
Complex fertilizers	1,439	1,696	1658	1138	−15
Ammonia	1,031	1,169	1091	882	−12
Urea fertilizers	973	1,166	1186	1126	−17
Polyvinyl chloride	232	192	131	116	21
Sodium carbonate	222	204	176	170	9
Fused phosphate	121	125	124	111	−3
Insecticides	72	79	80	94	−9
Synthetic detergents	64	70	64	48	−9

Source: Korean Bureau of Statistics

NOTE

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Big-volume acids: renewed strength rests mostly on phosphate exports
A Key Chemicals Review Page 8

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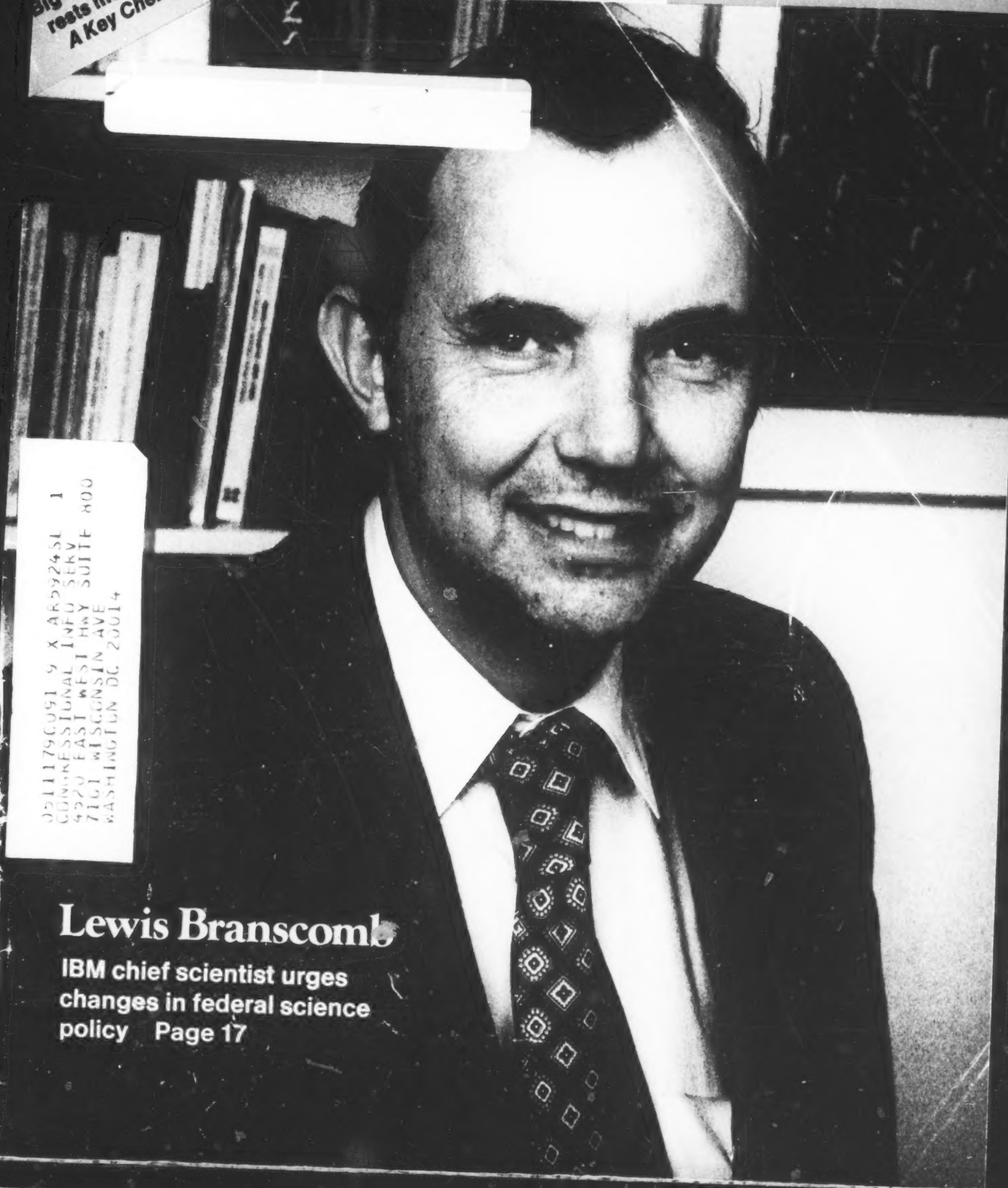

Lewis Branscomb

IBM chief scientist urges changes in federal science policy Page 17

June 15, 1981
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- ***Production of big-volume plastics*** *has increased but profits are being choked by widespread discounting.* ***Page 4***
- ***New patent procedures,*** *effective July 1, allow challenge to patent's validity without costly court proceedings.* ***Page 5***
- ***Physical chemist Lu Jiaxi*** *will head Chinese Academy of Sciences.* ***Page 5***
- ***The Iraqi nuclear research reactor*** *destroyed by Israeli bombs had the capability to make plutonium.* ***Page 5***
- ***Informal Gordon Research Conferences*** *mark their 50th anniversary.* ***Page 6***
- ***Phosphate shipments*** *are being resumed to U.S.S.R. by Occidental.* ***Page 6***

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- ***U.S. producers of big-volume acids*** *look for market revival after weak beginning in 1981 for downstream phosphates.* ***Page 8***
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- ***Industrial Innovation Conference*** *boosts small businesses by matching technologies with big companies' needs.* ***Page 11***

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- ***Western Europe's chemical industry*** *discouraged by first-quarter company results; data point to lackluster year.* ***Page 13***

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DISCOUNTING STUNTS PLASTICS' VALUE GROWTH

Although large-volume plastics have bounced back nicely in production and moderately in plant use since the recessionary depths of a year ago, they haven't yet done much for chemical company earnings. This despite a steady line of price increases this year.

The reason is discounts, which producers have been fighting this year while decontrolled oil prices have brought raw material cost increases. But the discounts themselves are symptomatic of a holdover condition from 1980 that is still throttling profits—a major pause in the plastics industry's dollar growth. It is taking time to re-establish the momentum of the late 1980's.

The dollar jolt that struck the plastics industry in 1980 is documented in a sweeping survey by the Society of the Plastics Industry's committee on resin statistics, with data compiled by accountants Ernst & Whinney. Covering most major thermosets and thermoplastics, except for polyurethanes and speciality plastics, the survey finds:

- No growth at all in the dollar value of the U.S. merchant market in 1980 from 1979.
- A 12% drop in merchant U.S. poundage in 1980 from 1979.
- An 11% average gain in value per pound in 1980.
- An 11% drop in U.S. plastics production in 1980.

Hence, the major commodity plastics in SPI's new survey are stalled with a U.S. market valued at about $10 billion. Since the specialty plastics add another $2.5 billion, the total plastics market, excluding polyurethanes, amounts to about $12.5 billion.

In physical volume, production of commodities and specialties was about 35 billion lb in 1980, down from 39 billion lb in 1979. The U.S. merchant market took about 27 billion lb in 1980, or 77%, with the remainder going mostly into captive use and exports.

Major plastics still gained 11% in value per pound in 1980

	Production (millions of lb)		Sales[a] (millions of lb)		Sales value[b] ($ millions)		Unit value[c] (cents per lb)	
	1980	Change from 1979	1980	Change from 1979	1980	Change from 1979	1980	Change from 1979
THERMOSETS								
Epoxy	315	−13%	264[d]	−4%	$ 282	−2%	99¢	2%
Polyester	947	−17	881	−18	535	−12	61	7
Urea	1,165	−15	1,077	−13	199	−3	18	6
Melamine	167	−16	123	−16	93	−5	75	12
Phenolic	1,499	−16	1,107	−19	530	−4	48	20
THERMOPLASTICS								
Low-density polyethylene	7,291	−6	5,323	−7	2109	5	40	14
High-density polyethylene	4,405	−12	3,460	−9	1322	7	38	19
Polypropylene	3,648	−5	2,483	−2	855	13	35	17
Acrylonitrile-butadiene-styrene	920	−23	858	−23	548	−2	64	28
Styrene-acrylonitrile	111	−10	85	−17	52	2	61	24
Polystyrene	3,521	−12	2,925	−17	1408	−1	48	20
Nylon	274	−16	229	−12	309	−3	135	11
Polyvinyl chloride	5,470	−11	4,230	−14	1415	−11	33	3
Polyvinyl alcohol	141	−5	115	−5	102	11	89	17
Other vinyls[e]	196	−11	102	−25	115	−4	113	28
TOTAL	30,070	−11%	23,291	−12%	$9874	0%	42¢	11%

a Domestic U.S. merchant sales, excluding exports and captive use. b Includes freight. c Average sales value per pound in U.S. merchant market. d Includes captive use. e Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene chloride. Source: Society of the Plastics Industry's committee on resin statistics as compiled by Ernst & Whinney

The average value per pound of leading commodities in the new SPI survey hit 42 cents in 1980, up 11% from 38% in 1979. Although this increase appears fair in view of the recessionary pressures, it contrasts poorly with the overall 17% price increase last year in the government's index for chemicals and allied products. It also contrasts poorly with the official 18% average 1980 price gain for plastics given by the government, indicating substantial discounting in the real market.

Certainly, 1980 was a big letdown after 1979. That year, SPI's dollar value survey showed a 23% jump in the U.S. merchant market and a 19% increase in the average value per pound. Sales poundage in the U.S. rose 7%, and production rose 11%.

A look down the 1980 SPI list of plastics shows clearly where the strengths and weaknesses lay. Polyolefins did the best, polyaromatics not too well, thermosets worse, and polyvinyl chloride wretchedly.

With more than 40% of U.S. merchant value and 50% of production in the SPI survey, the three leading thermoplastics—low- and high-density polyethylene and polypropylene—were obviously the top performers of the industry. Although each dropped in production and U.S. sales in 1980, each still managed to push up U.S. merchant value—5% in low-density polyethylene to $2.1 billion (tops for plastics), 7% in high-density polyethylene to $1.3 billion, and 13% (the biggest percentage gain for any plastic) in polypropylene to $855 million. Each polyolefin also boosted its unit value well above the average percentage gain—14% in low-density polyethylene to 40 cents per pound, 19% in high-density polyethylene to 38 cents, and 17% in polypropylene to 35 cents.

At the bottom is polyvinyl chloride. With U.S. unit value held to a gain of just a penny for the year, or 3%, the lowest increase of any large-volume plastics, PVC lost 11% of its U.S. market value in 1980. Since PVC production is more than five times that of polyester, its $174 million loss in market value was by far the largest for any plastic. Such a bath undoubtedly has much to do with widespread predictions of a shakeout in the next year or so in PVC. □

Acids producers look for market revival

Following weak first half in both U.S., export business in downstream phosphates, big-volume acid producers foresee improved second half

Has the countercyclical boom in the U.S. fertilizer phosphates business—and with it, a boom in precursor phosphoric and sulfuric acids—finally passed its high point after a very strong 1979 and 1980?

Acid producers say no, but they did get a scare over the past six to nine months. The U.S. downstream phosphates market was flat to falling from a year ago, and exports disappointed large producers. Inventories swelled.

At the moment, acids plants are still running at relatively high rates. However, pricing throughout the product chain has lost its former momentum, especially in end-product phosphates. Producers now talk about profitability problems as sizable cost increases hit them in raw materials, labor, and other operating factors.

The hope is that 1981 will repeat some of the second-half pattern of 1980. Most important, new export shipments are due, producers say, precipitated by the softened state of U.S. prices and the end of the embargo on Soviet trade. Then too, the U.S. market may tone up with a good fall season.

The acids business needs this sort of pickup. For the next few years, a lot of investment money has been earmarked for this product chain, running from phosphate rock and sulfur to finished phosphate fertilizers. The last thing producers want is a repeat of the overinvestment and torpedoed profitability of the late 1960's and mid-1970's.

At stake is a very large business in just the two acids alone. Sulfuric acid is the largest-volume U.S. chemical, and phosphoric acid ranks ninth (C&EN, May 4, page 37). Combined production value is expected to reach $7.25 billion in 1981, up from $6.85 billion in 1980. Combined volume will total more than 55 million tons as 100% acid, up slightly from 1980.

Of the total phosphoric acid production in 1981, all but 6% will be wet-process acid, some 9.7 million tons as P_2O_5. This wet-process acid will consume about 27.5 million tons of 100% H_2SO_4, two thirds of all sulfuric acid produced in 1981.

Almost all of the sulfuric acid used in making phosphoric acid is captively produced, generally on the site of the phosphoric acid plant. Often derivatives units are adjacent as well. Relatively little phosphoric acid is moved any distance in the U.S. because of high transportation costs.

Since two thirds of sulfuric acid goes into phosphoric acid and most phosphoric acid goes into fertilizers, the fertilizer business determines the health of these two acids. Currently, the market is just so-so. Export demand for phosphate fertilizers has been off from 1980 so far, and domestic demand from the producers' standpoint has been below 1980. So acid producers are in considerable suspense at the moment.

There are several views on the fertilizer outlook, all considering a worldwide perspective. If, as occurred this spring, export demand for phosphate fertilizers weakens, and domestic demand does no better because of weather and some loss of current sales due to an extra good fall 1980 season, producers face an inventory glut. However, if as occurred last summer, export demand surges, producers could face an inventory squeeze.

Currently, producers' inventories are relatively high for phosphate fertilizer materials, evidenced by price weakness in recent months. Producers expect they can handle anticipated sales until the third quarter begins, so some production units are down for maintenance now.

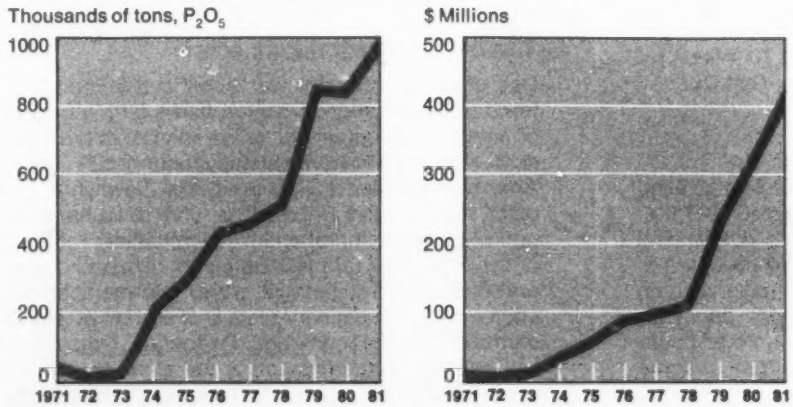
The expectation of adequate U.S. inventories also is based on estimates (really guesses) on inventories in countries that have been large buyers of phosphate materials. However, sources caution that inventory size by itself doesn't mean much in purchasing decisions by governmental agencies buying fertilizers in these countries. These countries have been known to overstock badly in the past.

Because exports now may come to life and because the various cost segments of phosphate fertilizers are all rising, few doubt that selling prices will go up this summer. U.S. producers think that foreign buyers know they have seen the low point in prices and will begin to place orders. Hence, prices are expected to rise, possibly quite rapidly if export sales should swell and resumed Soviet shipments tighten up the supply.

For details of the near-term outlook for the two big-volume acids, see the following pages.

Bruce Greek, Houston

Phosphoric acid exports still are expanding



Sources: Commerce Department, industry, and C&EN estimates

Key Chemicals

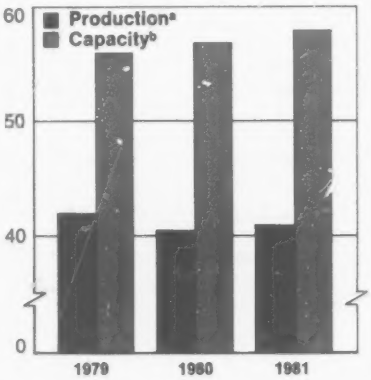
H_2SO_4

Sulfuric Acid

- ***Demand sluggish***
- ***Costs, capacity up***
- ***Profits squeezed***

PRODUCTION/CAPACITY

Millions of tons, 100% H_2SO_4



a From all sources. b First quarter.

HOW MADE

Sulfur dioxide from sulfur or smelter gases oxidized and reacted with water

MAJOR END USES

Fertilizers 70%; chemical manufacture, metals recovery, and petroleum refining, each 5%

FOREIGN TRADE

Exports—tiny, less than 100,000 tons, mainly to Canada and Mexico; imports—small, less than 500,000 tons, mainly from Canada

PRICES

Posted contracts, nonsmelter acid, $70 to $85 per ton of 100% H_2SO_4 (merchant sales less than 30% of production)

COMMERCIAL VALUE

$3.25 billion for total production, 1981

After last year's recession, this year is supposed to be one of recovery for sulfuric acid, the chemical used in the largest volume in the U.S. last year. Production is expected to increase about 1.5% over 1980 to 40.9 million tons. But much depends on the second half of the year to achieve this gain, and there is a big "if" now in the dominant phosphate fertilizer market.

Even if sulfuric acid output rises in 1981, it will not offset the 4% decline in 1980, when the recession hit hard on the nonfertilizer side of the acid's uses. The rest of the loss in production will not be made up until the end of 1982 and perhaps later if phosphate fertilizer exports fail to sustain a pickup. For 1981, there is guarded hope that exports will strengthen, if only from renewed phosphoric acid shipments to the Soviet Union.

Unfortunately, a big gain in plant capacity is due this year if plants under construction are completed this fall as anticipated. Nearly 2 million tons of new capacity are due on stream by year's end. This will bring total estimated nameplate capacity to more than 60 million tons per year, up from 58 million tons in first-quarter 1980. All of the new capacity is considered captive.

A big part of the new sulfuric capacity will be targeted for making phosphoric acid, used subsequently in phosphate fertilizer derivatives. Specifically, about 1.8 million tons of new 100% H_2SO_4 will be available in 1982 for phosphoric acid production in Florida and North Carolina.

How much of this capacity actually will be used in late 1981 and 1982 depends on several factors. As might be expected, the newest expansions will be the highest-capital-investment capacity with a strong incentive to operate as close to maximum output as possible.

Although supply of raw material sulfur has been tight, enough probably will be available to feed the new acid capacity. Roughly one third of a ton of sulfur is required for a ton of sulfuric acid. Hence, the new capacity could require about 600,000 tons of sulfur or 535,000 long tons (2240 lb each, the usual unit for elemental sulfur measurement). The requisite sulfur probably will materialize if imports rise and U.S. inventories are drawn down further. A small reduction in sulfur exports also could help the supply situation.

However, sulfur supply still will be snug, clearly indicating pressure on supply and potentially higher prices. Such sulfur cost increases plus other increases in plant operation costs add up to downward pressure on sulfuric acid profitability if sulfuric price increases run into resistance from a so-so phosphates market in the U.S. and abroad. Depressed prices this spring for phosphate derivatives could help keep sulfuric acid volume up, but not profits.

In other words, pushing up phosphates and sulfuric acid capacity use won't push up profitability if the mechanism is a price penalty in the fertilizer market.

Later this year, and in 1982, sulfuric capacity use will fall anyway as the new capacity comes on stream. By year-end 1981, capacity will be up more than 3% whereas output will do well to be up 1.5%. If this capacity alone, 60 million tons, were run in 1982 to produce an expected 42 million tons of sulfuric acid, the use rate would be 70%. This pace will be 71% in 1981 if output reaches 40.9 million tons this year.

Granted, the differences in these operating rates are small and too close to call accurately at the moment. However, they do indicate that overcapacity will exist for some time and profitability could be squeezed.

Helping offset the profitability squeeze for sulfuric acid in 1981 is a slower rate of metals smelting, which reduces pressure from by-product smelter acid on prices of merchant sulfuric. Smelter sulfuric is expected to be off 1% or so from 1980. Demand for this merchant acid—also known as industrial acid because most goes to nonagricultural uses such as oil refining or steelmaking—has been weaker than normal during the first quarter of 1981. Industrial acid is expected to rebound during the third quarter and improve in the fourth quarter probably to match 1980 consumption for all of 1981.

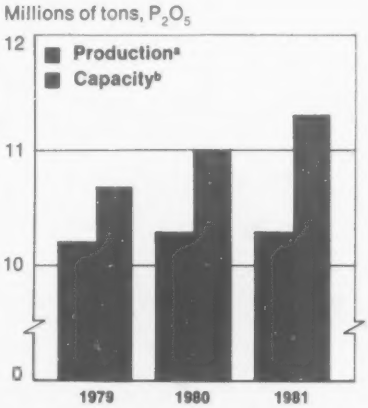
Still, fertilizer, with more than 70% of sulfuric acid consumption, will control sulfuric acid's fortunes this year. That was a healthy dependence in 1979 and 1980, but has become a potential liability in 1981 and 1982.

Phosphoric Acid

H_3PO_4

- ***Demand flat***
- ***Capacity growing***
- ***Prices struggling***

PRODUCTION/CAPACITY



a Both wet-process and furnace acid.
b First quarter.

HOW MADE

Reaction of phosphate rock and sulfuric acid; burning of elemental phosphorus and subsequent reaction with water

MAJOR DERIVATIVES

Ammonium phosphates 60%, triple superphosphate 20%

MAJOR END USES

Fertilizer 85%, animal feed 5%

FOREIGN TRADE

Exports—may exceed 1 million tons as P_2O_5 in acid; imports—negligible

PRICES

$425 per ton as 100% P_2O_5 for fertilizer

COMMERCIAL VALUE

$4 billion for total production, 1981

Prospects for 1981 production of phosphoric acid are still about the same as in 1980—all out or close to it. This despite a decidedly sluggish performance so far this year in the dominant market, phosphate fertilizer. The hope is that resurging exports will tighten up the phosphate scene.

Specifically, wet-process (that is, most) phosphoric acid producers in 1981 expect to run plants at high levels again, mainly because of the end of the U.S. government's embargo on fertilizer shipments to the U.S.S.R. Resumption of Soviet shipments this month could increase export demand in the form of superphosphoric acid by perhaps 400,000 tons (as P_2O_5) in 1981. All told, exports now are expected to take 40% or more of U.S. phosphoric acid production.

At the same time, other export demand for fertilizer phosphate derivatives might equal derivatives demand in 1980. U.S. demand, down slightly so far this year, could benefit from a strong fall season as in 1980.

Plant capacity, although due to increase in the last half of 1981 about 800,000 tons (as P_2O_5) to reach 10.0 million tons per year, has not increased appreciably during peak demand in the spring. This means that producers of wet-process acid will run their plants at 95% of nameplate capacity or even a bit more for all of 1981.

Some small amount of additional 1981 output can be expected from the expansions coming on stream this fall. Added phosphoric acid production is estimated at 200,000 tons (as P_2O_5) at most, but probably 100,000 tons is all that the industry can expect.

These production and capacity estimates exclude P_2O_5 in phosphoric acid and derivatives coming from elemental phosphorus. About 600,000 tons of P_2O_5 production equivalent will be phosphorus-based furnace acid, about the same quantity as in 1980.

Furnace acid nameplate capacity will stay about 1.3 million tons per year of P_2O_5. The operating rate again will be under 50% as it has been for some time. Some market prospects exist for increasing this rate. However, demand growth in the main outlet, detergents, remains low.

Demand for wet-process phosphoric acid is completely controlled by fertilizer uses, including a large foreign trade. The fertilizer industry has become worldwide in scope like the oil industry. However, unlike oil, it gives the U.S. a large international trade advantage. The U.S. will be a large net exporter of phosphoric acid and its derivatives for many years.

In extending itself worldwide, the phosphate fertilizer industry has become more complex in its production and marketing. Currently, for example, export sale prices for a major derivative, diammonium phosphate (DAP), have weakened with a drop in demand. This is partly because the final cost to foreign buyers has increased 10 to 20% over the past year, mostly because of a rise in transportation costs. At the same time, U.S. demand for DAP at the fertilizer dealer level has fallen because of the effect of high interest costs on inventories, backing inventories up to the producer level.

The hope now is that the combination of high producer inventories and lower prices will bring bargain hunters to the scene, just as in late spring and early summer 1980. As a result, some industry sources expect a surge in export demand for DAP this summer, restoring at least some of the price cuts. To date, though, big export contracts have had low prices.

China could become a larger buyer of phosphate fertilizer, some industry sources say. If China, for example, came into the market for 500,000 tons of P_2O_5 equivalent in fertilizers, prices would firm all over the world, according to one source. Such a demand increase, along with the Soviet pickup and other smaller increases, could shift the world picture from a reasonably ample supply condition to shortage. This indicates the relatively fragile equilibrium in the world phosphates business.

A lull in export business for phosphates now is giving U.S. producers a chance to do some needed maintenance on their plants and to work down inventories. The main question is whether plants, after the current maintenance shutdowns, will have to run at top speed as in 1980 or will start to reflect a reduced pace in downstream phosphates. The guessing is that a summer pickup is in the works because of increased exports.

European chemicals face lackluster year

This year's opening months have not been encouraging ones for Western Europe's chemical industry. First-quarter company results have been far from buoyant, and current statistical data point to a lackluster year ahead.

In West Germany, January's chemical production index fell sharply to 105 (1970 = 100) from 130 last December. Most of the loss was recovered in February and March, although, hovering around 120, the index was lower than at any time during the preceding three years. Moreover, the provisional April reading of 118 suggests that an upturn isn't imminent. The average first-quarter chemical production index value of 115 is 24% below that of last year's first quarter.

The situation in the U.K. was much the same. There, the January figure of 118 was off from December's 122. A slight recovery in February and March brought the first-quarter average to 122. But that's 12% below the like 1980 period.

France's position as yet is unclear. At press time, only a January production index value was available. But at 158, it is almost six points under December's, and 8% off from the January 1980 reading. France did better with chemical wholesale price index data, and the pattern is more encouraging. The steady month-by-month advance registered in 1980 continued during the first four months of this year. From a January reading of almost 281 (1970 = 100), the price index approached 295 in April, a 5% gain. The average for the first quarter of 1981 is 11% ahead of the 1980 first-quarter average.

In West Germany, too, chemical wholesale prices continue to improve. Between January and April, there was a gain of more than 4%. However, the 1981 first-quarter average is only 5% up on the January-to-March 1980 level.

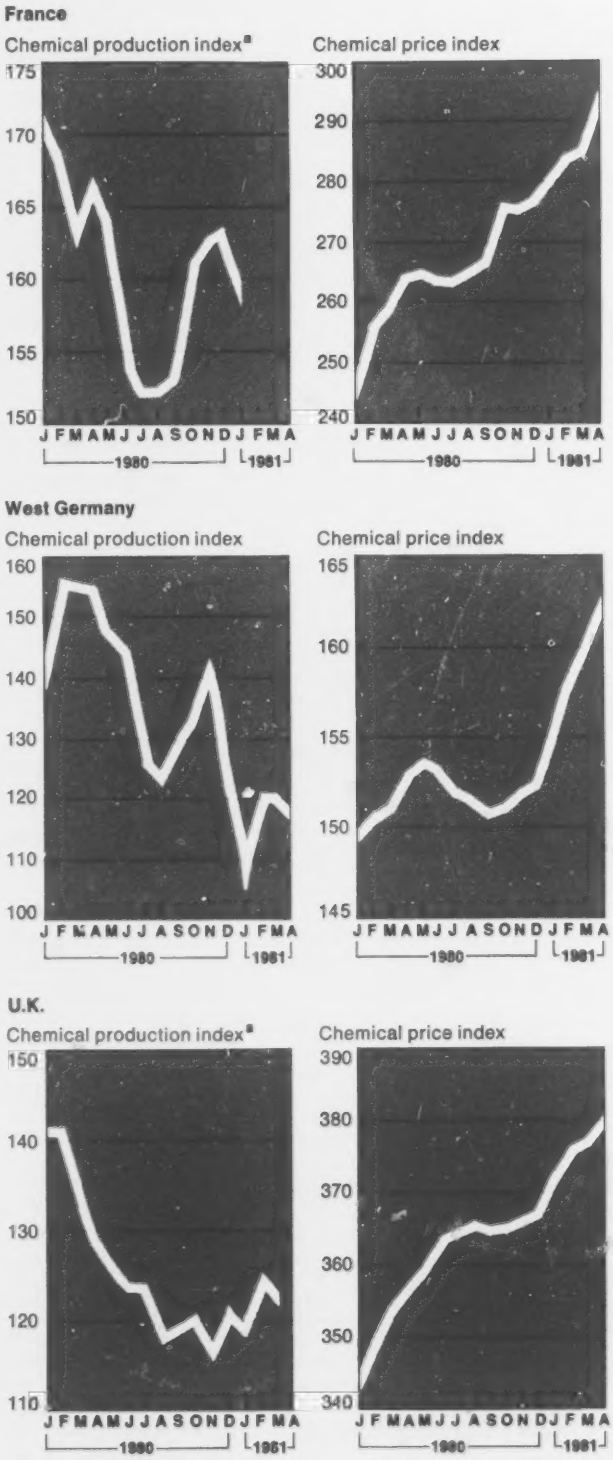
The U.K. fared poorest. From a January reading of 373, prices advanced a mere 2% to April's provisional 381. Comparing first-quarter averages, this year's shows a 7% improvement on 1980's.

The number of workers employed by West Germany's chemical industry has held remarkably steady, despite the slackening of overall output. Employment has been on the plus side of 548,000, essentially unchanged from 1980. The U.K., on the other hand, continues to cut back on its chemical labor force. In January, there were 3000 fewer employed than the 410,000 last December. There was a further drop of 4000 in February.

Despite the weak statistics, executives of West Europe's chemical industries appear confident of the medium- to long-term health of the industry. This week, for instance, key management people of Imperial Chemical Industries of the U.K. will be in Wilhelmshaven, West Germany, for the official opening of a 660 million lb-per-year vinyl chloride plant. This will be followed soon by a 338 million lb-per-year polyvinyl chloride plant.

Monsanto's chairman, John W. Hanley, in London earlier this month, commented, "1981 will be a more acceptable year for Monsanto in Western Europe." Monsanto intends to stay, he says, and will invest some $100 million a year there for the foreseeable future.

Dermot O'Sullivan, London



a Seasonally adjusted. **Note:** Base year for all indexes is 1970 = 100.

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ACS annual salary and employment survey Page 56

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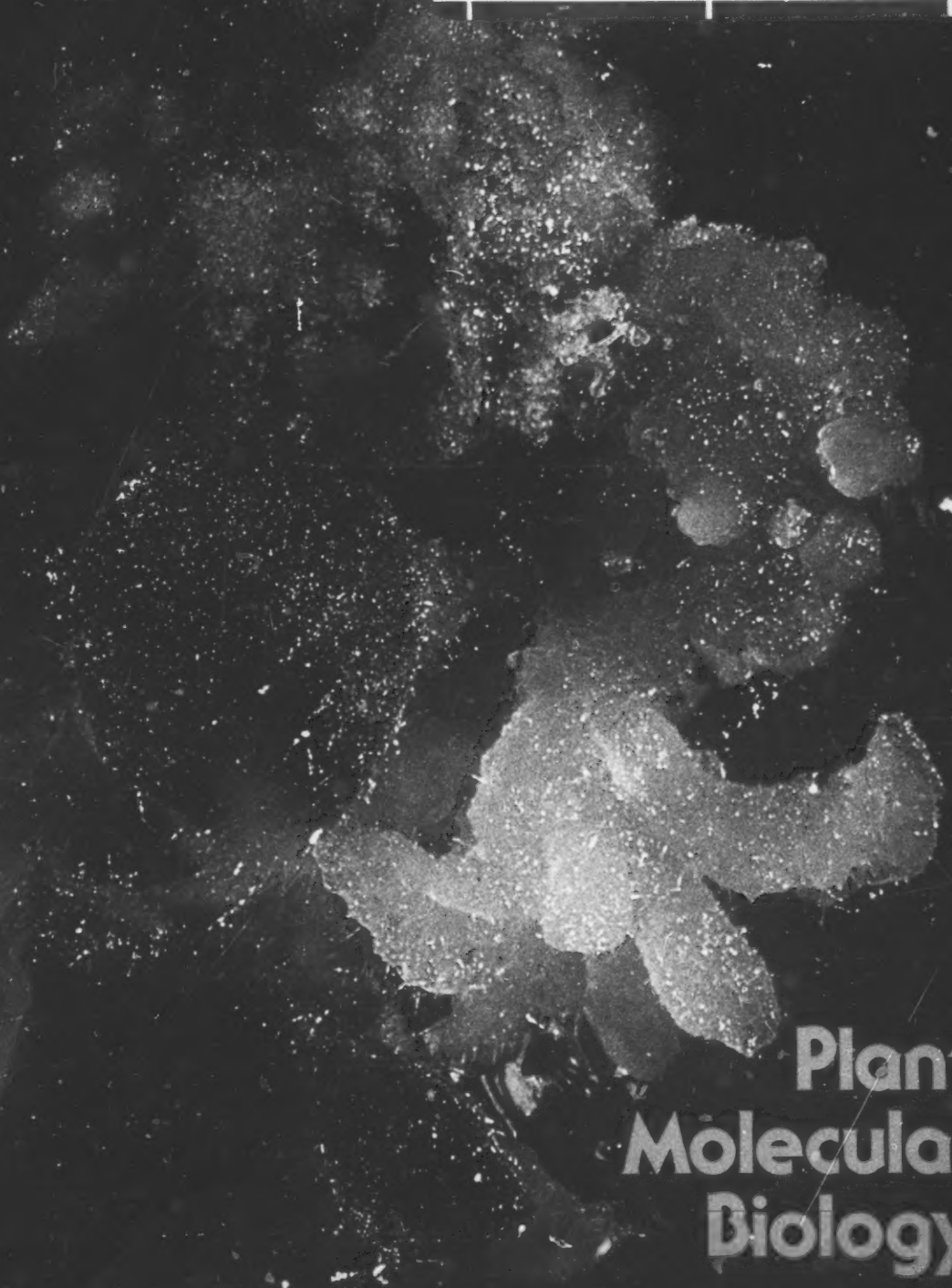

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The basic science accelerates
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Chemical & Engineering NEWS

Cover: Normal shoots growing out of plant tumor mass caused by infection with genetically engineered *Agrobacterium tumefaciens*. Photo courtesy of Jeff Schell, Max Planck Institute for Plant Breeding, Cologne, West Germany. Photo by M. Kalda

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Salary Survey

Chemists' median salaries increased *11% since March 1980, holding out against inflation better than in previous years; unemployment remained low.* ***Page 56***

Chemists' salaries move higher this year

Increase of 11% in chemists' median salary about matches rise in living costs; unemployment remains low among ACS members

The employment status of U.S. chemists continues to be relatively sound this year. Very few members of the American Chemical Society were out of work and looking for a job as of last March. Generally speaking, too, salaries for chemists working full time increased more during the past year than in any year of the past decade, according to the latest annual ACS survey of the economic status of its members. In fact, salaries overall held their own against the steady onslaught of inflation to a greater degree during the past year than at any time since 1973.

All in all, the median salary for chemists (that is, the salary which is exceeded by 50% of the chemists participating in the survey) increased 11% between March 1980 and March 1981. The median had increased 7% in 1980 and had been rising only about 6 to 7% a year during most of the past 10 years.

The biggest increase this year is for chemists whose highest degree is an M.S.; their median salary had increased least in the previous two years. Chemists with no more than a B.S. degree fared the poorest; even so, the 10% rise in their median salary was greater than in any year of the recent past. And for the first time in many years, too, the median salary for B.S. chemists was up more than the wage rate paid to production workers in the chemical industry. Average hourly earnings for blue-collar workers in chemical plants increased 9% between March 1980 and March 1981.

Chemists' salaries also increased more than those for chemical engineers surveyed by ACS, a reversal of the usual trend. Nevertheless, median salaries of ACS-member engineers are about 20 to 30% higher at any degree level. Chemical engineers, however, make up a small part—just 10%—of the survey sample. In addition, these engineers form a group that is skewed toward older, more experienced—and hence generally better-paid—individuals than is the case with the chemists surveyed; 43% of the engineers earned their bachelor's degree 30 or more years ago, whereas only 25% of the chemists are that far from having graduated with a B.S.; on the other hand, 36% of the engineers received their bachelor's degree less than 20 years ago, compared to 50% of the chemists.

Factor in the continuing inflation of the past 12 months, however, and the salary increases won by chemists during this period look nowhere near so good. Between March 1980 and March 1981, the cost of living, as measured by the Bureau of Labor Statistics' consumer price index, climbed about 10.5%. That is enough

Salaries generally are higher for chemists in industry, whatever their degree or years since B.S.

CHEMISTS' ANNUAL SALARIES ($ THOUSANDS)[a]

Years since B.S. degree	0 to 1		2 to 4		5 to 9		10 to 14		15 to 19		20 to 24		25 to 29		30 to 34	
Percentile	All	Industrial	All	Industrial	All	Industrial	All	Industrial	All	Industrial	All	Industrial	All	Industrial	All	Industrial
B.S.																
90%	$24.0	$24.6	$23.9	$25.0	$30.0	$30.0	$38.0	$39.9	$43.2	$45.0	$45.4	$48.0	$49.7	$50.0	$52.4	$55.6
75%	21.0	21.3	21.7	22.0	25.2	25.8	32.0	33.0	35.1	36.9	39.0	39.6	40.0	41.7	44.0	45.0
Median	17.9	18.0	19.0	19.9	22.0	22.5	27.0	28.0	30.0	31.4	32.4	32.2	34.5	35.0	35.5	36.3
25%	15.3	16.0	16.4	17.2	19.0	19.8	23.4	23.6	24.5	25.5	28.0	28.7	29.0	29.0	29.9	30.0
10%	12.7	13.9	14.5	15.5	16.8	17.0	20.5	21.0	21.0	22.0	23.0	24.0	24.0	24.7	24.0	25.0
M.S.																
90%	—	—	25.0	25.0	29.0	29.3	37.5	38.9	44.0	45.8	48.5	50.0	56.4	60.0	52.1	55.2
75%	—	—	24.0	24.5	25.8	26.6	31.5	33.2	37.0	38.6	38.4	42.4	43.5	45.9	43.9	45.0
Median	—	—	23.0	23.0	22.5	23.5	27.0	29.0	31.7	33.1	32.0	35.0	35.0	38.7	36.0	38.0
25%	—	—	19.6	20.0	19.1	21.0	22.1	25.0	25.9	27.0	25.0	30.3	28.0	30.0	30.0	33.0
10%	—	—	16.5	18.5	16.0	19.0	17.5	21.0	19.8	23.0	19.5	25.5	23.0	27.0	23.5	29.9
Ph.D.																
90%	—	—	—	—	34.0	34.5	40.0	42.2	46.0	49.9	52.0	60.0	56.0	65.6	65.0	70.0
75%	—	—	—	—	31.5	32.0	35.0	37.1	40.0	43.0	44.0	48.9	48.0	53.0	52.0	59.5
Median	—	—	—	—	29.0	30.0	30.0	33.5	33.0	38.0	36.0	42.4	38.1	45.0	45.0	48.0
25%	—	—	—	—	25.0	28.5	23.5	30.0	25.0	33.0	28.8	36.9	30.5	38.0	35.0	40.0
10%	—	—	—	—	17.0	26.1	18.0	26.5	21.0	29.0	22.9	32.0	24.8	32.4	29.0	35.0

a As of March 1, 1981. **How to read this table:** Using as an example all B.S. chemists two to four years after having received their B.S. degree, 90% of these chemists have salaries of $23,900 or less, 75% have salaries of $21,700 or less, 50% have salaries of $19,000 or less, 25% have salaries of $16,400 or less, and 10% have salaries of $14,500 or less, as of March 1, 1981. Source: ACS survey

Few ACS members were not employed last March . . .

Employment status[a]	Chemists: Total	By sex: Men	By sex: Women	By highest degree: B.S.	By highest degree: M.S.	By highest degree: Ph.D.	By minority status: Minority[b]	By minority status: Nonminority	Chemical engineers	All ACS members[c]
Employed full time	94.8%	95.7%	87.8%	94.9%	96.3%	94.2%	93.4%	95.0%	95.1%	94.8%
Employed part time	1.1	0.8	3.0	1.4	1.0	0.9	0.6	1.1	2.0	1.3
Postdoctoral or fellowship	2.2	2.0	3.9	0.4	0.7	3.6	4.9	1.9	0.3	1.8
Unemployed										
Seeking employment	1.1	0.9	2.4	1.6	1.2	0.8	0.6	1.1	1.1	1.1
Not seeking employment	0.8	0.6	2.9	1.6	0.8	0.5	0.6	0.9	2.0	1.3

a As of March 1, 1981. b Black, American Indian, Alaskan native, Asian or Pacific, Hispanic, or other. c Includes members whose highest degree and present work is neither in chemistry nor chemical engineering. **Source:** ACS survey

. . . and those at work were earning more money than the year before

$ Thousands	1981	1980	1979	1978	Change 1980–81
CHEMISTS' MEDIAN SALARIES					
B.S.	$27.5	$25.0	$23.5	$22.0	10%
M.S.	30.0	26.0	25.0	24.0	15
Ph.D.	35.0	31.2	29.0	27.4	12
All chemists	32.0	28.9	na	na	11

$ Thousands	1981	1980	1979	1978	Change 1980–81
CHEMICAL ENGINEERS' MEDIAN SALARIES					
B.S.	$36.0	$35.0	$31.7	$30.0	3%
M.S.	40.0	35.0	31.5	32.0	14
Ph.D.	42.0	38.0	35.0	32.0	11
All	39.2	36.0	na	na	9

na = not available. **Source:** ACS survey

to wipe out all the gain in the median salary for B.S. chemists and to limit that for M.S. chemists to less than 5% and that for Ph.D.'s to less than 2%. On a constant-dollar basis, chemists' salaries are down 15 to 20% since 1973. And they are no higher now than they were in the mid-1960's. These data, moreover, do not reflect the impact of higher taxes and social security payments on take-home income. (Nor, of course, do they take into account any changes in fringe benefits, such as improvements in pension plans, medical insurance coverage, vacation and holiday time, and the like.)

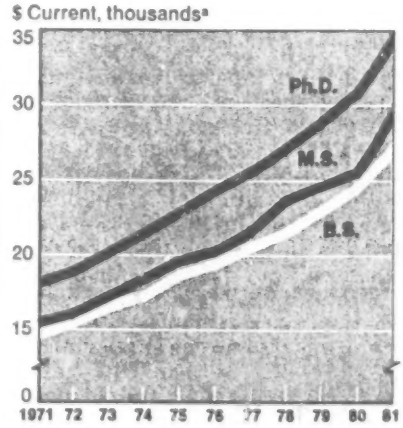
The overall median provides only a rough measure, to be sure, of what individual chemists actually earn. Their salary depends, in turn, on who they are, what they do, where they work, and how much experience they have. Thus younger, less-experienced chemists typically are paid less than their older colleagues. And over the long run, salary increases resulting from increased experience have helped alleviate the impact of inflation.

Five years ago, for example, the median salary for B.S. chemists with just a couple of years of work experience in industry was $13,300 a year. These same chemists, if they are still in industry and earning at the median level for people with their experience,

35 to 39: All	35 to 39: Industrial	40 or more: All	40 or more: Industrial	Overall: All	Overall: Industrial
$60.0	$63.7	$60.0	$60.0	$45.0	$46.5
49.0	49.6	47.5	47.4	35.1	36.0
36.2	38.5	38.0	38.2	27.5	28.0
28.5	29.0	30.2	31.8	21.5	22.0
24.0	24.1	25.0	25.2	17.6	18.2
55.0	61.9	60.8	67.0	47.2	50.0
42.4	49.0	49.0	53.0	38.0	40.0
35.5	39.0	37.0	41.0	30.0	31.8
27.9	31.2	30.0	32.0	23.5	25.5
20.5	23.8	24.2	28.7	19.0	21.4
64.0	71.4	65.0	75.0	53.0	60.0
52.0	60.0	52.0	60.0	44.0	48.0
43.2	48.0	43.0	49.7	35.0	39.0
35.0	40.0	35.1	40.0	27.9	32.2
27.9	35.0	28.5	35.0	21.4	28.7

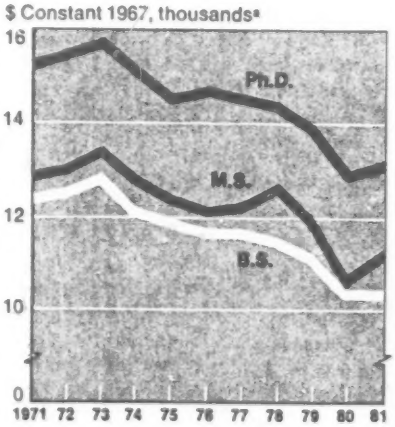
Chemists' salaries continue to rise this year . . .

$ Current, thousands[a]



. . . and even make a little headway against inflation

$ Constant 1967, thousands[a]



a Median annual salary of chemists as of March of each year. **Source:** ACS survey

Faculty earn highest salaries at schools offering Ph.D.

Type of institution and highest degree awarded in chemistry	Median salary, Ph.D. chemists ($ thousands)			
	Professor	Associate professor	Assistant professor	All Ph.D. chemists[a]
PRIVATE				
Ph.D.	$40.0	$26.2	$21.9	$29.0
M.S.	30.0	23.6	17.1	26.0
B.S.	24.0	20.2	16.8	21.0
PUBLIC				
Ph.D.	36.6	26.0	20.3	29.3
M.S.	29.5	22.7	18.0	25.6
B.S.	29.5	22.0	18.0	24.0
ALL UNIVERSITIES AND COLLEGES[b]	32.5	24.0	19.1	26.2

a Includes instructors, unranked faculty members, and nonfaculty employees. b Includes schools where highest degree offered in chemistry is Associate. **Source:** ACS survey

Salaries highest for industrial chemists with oil firms

Industry	% of industrial chemists				Median salary ($ thousands)			
	All chemists	B.S.	M.S.	Ph.D.	All chemists	B.S.	M.S.	Ph.D.
Chemical	31%	28%	29%	36%	$36.0	$30.0	$34.0	$39.5
Pharmaceutical	17	16	19	17	33.0	26.2	29.3	40.0
Petroleum	7	5	6	8	40.0	32.0	35.7	43.0
Coatings	6	9	6	4	32.0	29.1	31.5	36.5
Food	4	5	4	3	31.0	24.3	31.0	35.0
Metals and minerals	3	4	4	2	30.3	25.0	29.1	38.0
Rubber	3	4	3	2	37.0	29.3	34.0	41.1
Paper	2	1	1	2	32.7	25.7	30.0	37.0
Other manufacturing	20	20	20	20	33.0	27.0	31.0	37.6
Nonmanufacturing	7	8	8	7	30.9	23.6	29.0	37.0

Source: ACS survey

Salaries are highest for managers in industry

Median salary, $ thousands[a]	B.S.	M.S.	Ph.D.
WORK FUNCTION			
General management	$38.5	$37.6	$53.5
R&D management	38.0	41.4	47.3
Marketing	33.6	33.7	40.4
Basic research	22.7	27.0	36.0
Applied R&D	25.5	29.0	35.3
Production and quality control	24.5	28.2	35.5
SPECIALTY			
Organic	$30.5	$32.0	$40.0
Polymer	30.0	34.0	40.0
Agricultural, food	29.0	34.0	40.0
Physical	28.8	35.5	39.9
Biochemistry	27.6	29.2	40.0
Pharmaceutical	27.0	31.0	40.0
Environmental	26.9	28.6	38.4
Analytical	25.0	29.4	35.0

a As of March 1, chemists in private industry only. **Source:** ACS survey

Salaries increase as the level of supervision rises

Number of subordinates	Median annual salaries,[a] chemists in private industry ($ thousands)		
	B.S.	M.S.	Ph.D.
ALL SUBORDINATES			
1–2	$28.0	$30.0	$36.9
3–7	30.0	33.2	39.0
8–12	35.0	37.3	44.0
13–17	40.0	40.4	44.6
18–22	36.0	39.5	49.8
23–32	36.5	43.8	52.5
33–47	44.0	53.0	55.0
48–67	49.6	52.0	57.1
68–99	52.0	52.5	62.0
100 or more	60.0	60.0	63.7
PROFESSIONALS AND TECHNICIANS ONLY			
1–2	$28.4	$30.1	$37.0
3–7	30.2	34.0	39.0
8–12	37.0	37.7	44.0
13–17	40.0	41.0	45.0
18–22	39.8	43.5	50.2
23–32	40.5	49.0	53.2
33–47	50.0	53.0	58.5
48–67	—	—	56.5
68–99	—	—	64.0
100 or more	—	—	76.0

a As of March 1. **Source:** ACS survey

now are making $22,500. That's an increase of about 70%. During the same period, consumer prices rose nearly 60%. Therefore, these younger chemists, at least, have managed to keep a little ahead of inflation—even though the median for all B.S. chemists rose less than 40% during the five years since 1976.

Chemists who graduated with a B.S. about a dozen years ago and went to work in industry now are being paid (if their salary has held at the median level) about 75% more than they were five years ago and 160% more than a decade ago. They, too, have been able to keep just a bit ahead of inflation. (The cost of living has risen about 120% in the past 10 years.) But though their salary has increased at an annual clip of about 10% since 1971, once you take into account the rise in living costs during the same period, the annual increase works out to less than 2% a year.

For older chemists, the comparison is less favorable. Increases in median salaries with experience tend to be appreciably less among older chemists, the ACS survey indicates, than among younger ones. For instance, the median for industrial chemists with a B.S. degree and 15 to 19 years' experience is nearly 60% higher than that for similar chemists having just two to four years' experience. But the median for those with 30 to 34 years' experience is only 15% higher than that for the group with 15 to 19 years on the job.

In light of this, a B.S. chemist who has worked 32 years in industry (and, again, earns a salary that matches the median level for individuals with the same experience) is being paid $36,300 a year. Ten years ago, that chemist was making $17,000 a year; five years ago, $24,000. Increases of 110% in 10 years and 50% in the past five years have not quite kept up with the rise in consumer prices. In 1971 dollars, as it turns out, that $36,300 salary is worth just $16,400 a year.

Sex is also a determinant of salary levels. Men typically have had a clear edge on women in the chemical profession. Some data in the past few years have suggested that this edge may be diminishing, but it is difficult to make a strong case that this is indeed so from the latest survey figures.

The median salary for women working in industry, for example, is only 71% of that for men if they both have a B.S. degree and 78% if they have earned a Ph.D. These percentages have not changed appreciably during the past five years. In fact, this year the percentage differences are slightly lower than they were in 1980. (Corresponding data for academic chemists were not available at press time.)

It is important to recognize, of course, that the demographic characteristics of women in the chemical profession are significantly different from those for men, which can explain at least part of the discrepancies in median salaries.

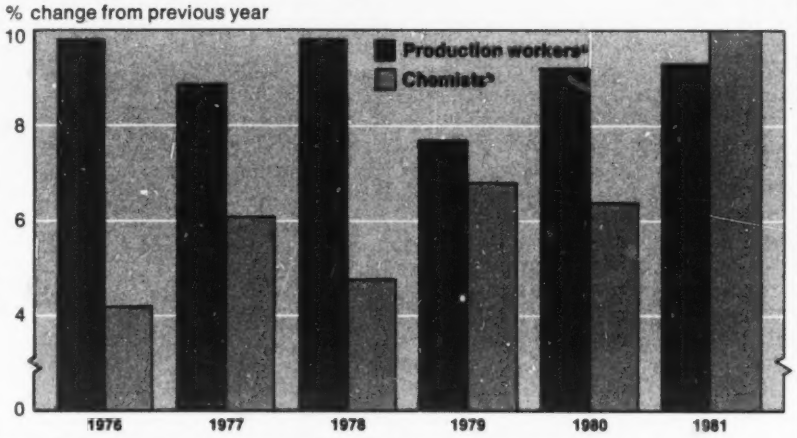
Women as a group, for one thing, have considerably less work experience than men. Among nonacademic chemists with a B.S. degree, for instance—and 47% of the women surveyed have not advanced beyond the bachelor's level, whereas 70% of the men have done so—almost two thirds of the women graduated less than 10 years ago and only a fifth have worked for 20 years or more. For similar men, on the other hand, less than a third have less than 10 years of experience and close to half have 20 years or more.

The difference between overall salaries of men and women cannot be attributed, nevertheless, just to the youth and lower experience of the women. If the data from the 1981 ACS survey for men and women chemists with nonacademic jobs are adjusted to eliminate the factor of experience, women's salaries still are appreciably lower than men's salaries—ranging from 79% of men's for B.S. chemists to 84% for Ph.D. chemists.

On the other hand, differences between median salaries are considerably smaller for relatively recent graduates. Among Ph.D. chemists working in industry, in fact, the median is the same for both women and men if they are less than 10 years away from having obtained their B.S. degree. For industrial chemists who do not have a degree beyond the B.S. level, median salaries for women are only 5 to 7% less than those for men if they have graduated less than 10 years ago, although they fall off to more than 20% below men's salaries if 15 to 19 years have passed since they received their degree.

It is among more experienced chemists, therefore, that sex seems to make the greatest difference in salary. The number of women chemists working in nonacademic jobs who graduated with a B.S. more than 20 years ago, however, is so small that it is impossible to make a quantitative comparison based on the ACS survey. (All in all, only about 12% of the ACS chemists surveyed are women. About two thirds of them work in nonaca-

Chemists' salaries rose more in past year than plant workers' wages for a change



a Average hourly earnings in chemicals and allied products industry. b With B.S. degree.
Sources: Bureau of Labor Statistics, ACS survey

Women chemists tend to have lower salaries than men, wherever they work . . .

Median salary, $ thousands[a]	B.S. All chemists	B.S. Men	B.S. Women	B.S. Women as % of men	M.S. All chemists	M.S. Men	M.S. Women	M.S. Women as % of men	Ph.D. All chemists	Ph.D. Men	Ph.D. Women	Ph.D. Women as % of men
BY EMPLOYER												
Private industry	$28.0	$30.0	$21.4	71%	$31.8	$32.5	$27.2	84%	$39.0	$39.7	$31.0	78%
Government	28.0	29.0	23.1	80	30.0	30.5	25.0	82	36.3	37.0	30.0	81
College/university	19.6	20.0	18.2	91	21.4	22.0	16.4	75	26.2	27.0	21.4	79
Other nonacademic	23.5	24.2	19.0	79	27.0	30.0	20.9	70	35.0	35.6	25.5	72

. . . although the differential is less among more recent graduates

Median salary,[a] nonacademic chemists ($ thousands)

Years since B.S. degree	B.S. Men	B.S. Women	B.S. Women as % of men	M.S. Men	M.S. Women	M.S. Women as % of men	Ph.D. Men	Ph.D. Women	Ph.D. Women as % of men
2 to 4	$19.6	$18.5	95%	—	—	—	—	—	—
5 to 9	22.7	21.0	93	$23.0	$22.0	96%	$30.0	$30.0	100%
10 to 14	27.6	24.0	87	28.5	27.0	95	33.0	29.4	89
15 to 19	31.9	25.0	78	33.5	29.6	88	37.0	33.6	91

a As of March 1. **Source:** ACS survey

demic jobs, but only a quarter of these women obtained their B.S. degree more than 20 years ago.)

Factors other than experience also are involved in determining salary levels, of course. Management jobs tend to be the highest-paying positions for chemists in industry. Thus a chemist supervising more than 30 employees, directly or indirectly, is likely to earn at least 50% more than one who has only one or two subordinates. But whereas 28% of the men working in industry consider themselves to be either general managers or managers of research and development, according to the ACS survey, only 13% of the women work as managers.

Similarly, industrial chemists whose specialty is analytical chemistry tend to have lower salaries than those who work in other areas of chemistry. Whereas 36% of the women chemists in industry are analytical chemists, only 21% of the men are.

As was the case last year, industrial chemists' salaries are highest if they work, as 7% do, for petroleum firms. But chemists working for companies that manufacture chemicals—which, not surprisingly, employ more chemists than companies in any other single industry—also earn salaries that are higher than those in most other industries. Median salaries are lowest for chemists with metals and minerals producers, food companies, and nonmanufacturing firms.

Although salaries are higher this year, unemployment continues at a very low level for ACS members. Only 1.1% of the chemists were out of work and seeking a job last March 1. That's a slight but hardly significant change from the 0.9% that were looking for work a year earlier—and far below the 7.3% unemployment rate for the entire U.S. labor force last March or even the 2.7% rate for all professional and technical employees. Unemployment among chemists has held to 1% for the past three years.

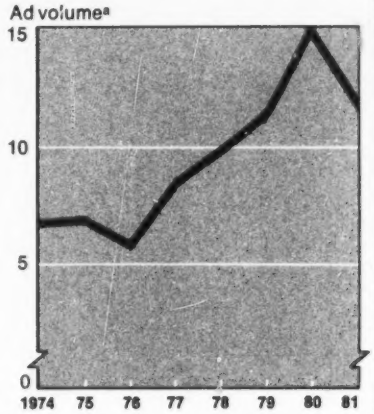
Unemployment generally is low no matter what a chemist does or where he or she does it. As has usually been the case in the past, it is slightly higher for B.S. chemists than for those who have a graduate degree. Unemployment also continues to be appreciably higher for women than for men. It also is slightly higher on the West Coast than elsewhere in the U.S., as has often been the case previously; in general, though, differences are slight from one geographic region to another.

Although chemists appear to have ridden out last year's recession with little loss of jobs, a change in the job climate at least is being hinted at by the current volume of employment advertising. C&EN carries more classified ads for job openings in chemistry than any other U.S. magazine, and in the past changes in the amount of this advertising have paralleled changes in the unemployment rate. Ad volume in C&EN remains well above the level of most of the past 10 years or so, but generally it has been trending downward since last summer.

Most of these data on the economic status of the chemical profession are based on nearly 11,300 responses to a survey conducted last March by the Office of Manpower Studies of the ACS Department of Professional Relations & Manpower Studies. The survey was limited to members who are not older than 70, have U.S. mailing addresses, and have neither student nor emeritus status.

The Office of Manpower Studies will publish a full report on the 1981 survey, with more detailed data on employment status and salaries of ACS members, next month. The report, "Salaries 1981," can be purchased from Special Issues Sales, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. The price is $25 a copy. □

Job ads fall for first time since 1976



a Volume of help wanted advertising (in thousands of column inches) in C&EN for the 12 months ending with May of each year.

Joblessness among chemists continues to hover near 1%

Employment status, total U.S.[a]	1981	1980	1979	1978	1977	1976	1975	1974
Employed full time	95.6%	95.9%	95.0%	95.7%	95.4%	94.7%	95.0%	95.1%
Employed part time	1.1	1.0	2.0	2.0	1.1	1.3	1.3	1.0
Postdoctoral or fellowship	2.2	2.2	1.9	1.9	2.1	2.2	2.0	2.5
Unemployed	1.1	0.9	1.1	1.4	1.5	1.9	1.6	1.4

a Excludes unemployed chemists not seeking employment. **Source:** ACS survey

Unemployment is low whatever a chemist does

	% in category	% unemployed[a]
MOST RECENT EMPLOYER		
Industry	62.0%	1.1%
Chemical	19.4	0.8
Other	42.7	1.2
Education	22.8	0.7
Government	10.0	0.8
Other	5.2	3.2
MOST RECENT WORK FUNCTION		
R&D	36.7%	0.8
Teaching	23.4	0.7
Management[b]	19.6	1.0
Marketing, production	11.4	1.7
Other	9.0	1.9
MOST RECENT WORK SPECIALTY		
Analytical	20.1%	1.3%
Organic	16.9	0.6
Polymer	11.9	1.2
Physical	9.3	0.7
Pharmaceutical	8.9	1.5
Biochemistry	7.4	1.1
Environmental	6.8	0.8
Agricultural, food	4.3	1.1
Other	14.4	1.2

a Excludes unemployed chemists not seeking employment. b Includes R&D management. **Source:** ACS survey

Age has little impact on unemployment

Age	% in category	% unemployed[a]
20–24	1.9%	2.4%
25–29	10.7	0.9
30–34	15.8	1.5
35–39	16.5	0.8
40–44	13.3	0.8
45–49	11.0	1.0
50–54	11.6	1.1
55–59	10.3	1.6
60–69	9.0	0.5

a As of March 1, 1981; excludes unemployed chemists not seeking employment. **Source:** ACS survey

NOTE

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Chemistry of Fireworks

Moving from art to science
Page 24

0511179C091 9 X AR5926SL 1
CONGRESSIONAL INFO SERV
4520 EAST WEST HWY SUITE 800
7101 WISCONSIN AVE
WASHINGTON DC 20014

June 29, 1981
Volume 59, Number 26
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up a new career while I'm able to do that," says Fredrickson, who is 55.

Nevertheless, the suddenness of the announcement and the immediate lack of a specific position elsewhere has caused rumors to circulate at NIH that Fredrickson was pressured to leave to clear the way for an appointee of the Reagan Administration.

However, Fredrickson says that the suddenness of his resignation from a job that will take some searching to fill was prompted by a number of high-level openings at NIH. Recruiting for these positions can't be carried out unless prospective appointees can be assured that the director will be there for several years, Fredrickson explains. He says he didn't want to be a "lame duck" director. □

Chemical workplaces hazardous, study says

Despite a decline in injuries and illnesses, the chemical industry remains a hazardous place in which to work, concludes a study by New York City-based Council on Economic Priorities, which analyzed records of more than 12,000 inspections the Occupational Safety & Health Administration made of chemical workplaces between 1972 and 1979.

According to the study, OSHA has had a positive effect at very little cost on the chemical industry over the decade the agency has been in existence. Between 1972 and 1979 there was a 23% decline in the industry's occupational injury and illness rate, while the industry spent little more than $1.4 billion to comply with OSHA standards, or about $1275 per employee, representing 1.8% of the industry's total capital investment per employee.

Of 12,758 OSHA inspections, 518 resulted from accidents, 3587 from workers' complaints, 2722 followed up previous inspections, 5946 were general scheduled inspections, and 85 were part of ongoing monitoring programs.

The CEP study breaks out data on health and safety records of the eight largest chemical companies—Allied Corp., American Cyanamid, Celanese, Dow Chemical, Du Pont, Monsanto, W. R. Grace, and Union Carbide. The data show that accident inspections as a percentage of all inspections were 8.9% for these companies compared to 4.1% for the entire industry.

Of the 114,652 violations of OSHA regulations for which the chemical industry was cited between 1972 and 1979, nearly 84% were in the area of safety, 13% were health, and 3% were general duty (in which no specific OSHA compliance standard is applicable, usually in the health area) violations. In terms of severity, about 50% of the health and 82% of the safety violations were considered not serious, whereas 100% of the general duty, 50% of the health, and about 18% of the safety violations were serious.

On an individual company basis, W. R. Grace's average violation record per inspection exceeded the 8.99 industry average 50%, Du Pont 31%, Allied 12%, and Celanese 3.5%. On the other hand, Monsanto and Dow ran 48% below the industry average, Union Carbide 58% below, and American Cyanamid 63% below. But when the severity of the violations is taken into account, Du Pont had the highest average number of serious violations per inspection with 8.95.

Du Pont chairman Richard E. Heckert responded immediately to the CEP study, saying, "It presents a distorted and misleading view of Du Pont." He says it is unfortunate that the study used raw government data to assess the success or failure of a company's or industry's safety and health programs.

"The best and generally accepted measure," he says, "is the number of lost-time injuries and occupational illnesses as compiled by the U.S. Bureau of Labor Statistics.... These conclusively show that Du Pont has the best health and safety performance in the chemical industry." □

Top companies averaged below industry for violations per OSHA inspection

Violations per inspection, 1972–79	General duty	Health	Safety and other	Total
Du Pont	0.07	0.29	11.40	11.76
Dow Chemical	0.21	0.94	3.47	4.62
Union Carbide	0.03	0.12	3.63	3.78
Monsanto	0.48	0.72	3.45	4.63
W. R. Grace	0.04	0.94	12.47	13.45
Allied Corp.	0.04	1.80	8.19	10.03
American Cyanamid	0.00	0.04	3.30	3.35
Celanese	0.13	2.82	6.34	9.29
AVERAGE, eight companies	0.11	0.87	6.99	7.97
AVERAGE, total chemical industry	0.25	1.20	7.53	8.99

Conoco, Cities Service merger plan aborted

As industry analysts thought it might, the flurry over the past month on ownership of Conoco's Canadian oil and gas interests has set off a bidding spree for Conoco itself (C&EN, June 8, page 7). The most likely combination appeared to be Conoco and Cities Service. Last week both companies stopped trading in their stock.

However, at press time, distillers Joseph E. Seagram & Co. initiated a $2.56 billion tender offer for 35 million shares, or 32%, of Conoco's shares at $73 per share. On learning this, Cities Service president Charles J. Waidelich notified Conoco that Cities Service is breaking off merger negotiations.

A merger of Conoco and Cities Service would, among other things, have created a new $1.4 billion chemical enterprise, about the 25th largest in the U.S. In 1980, Conoco's chemicals sales of $875 million ranked 43rd in C&EN's Top 50 (C&EN, May 4, page 40), and Cities Service's chemical sales of $557 million ranked 57th (page 8).

In chemical product terms, this merger would have linked Conoco's interests, largely in vinyl plastics and surfactants, with Cities Service's operations in basic olefins and aromatics, polyolefins, carbon black, and ore-based chemicals. Conoco also has a joint operation with Monsanto at Chocolate Bayou, Tex., making basic olefins and aromatics.

The lure behind various companies' interest in merging with Conoco is its recent receipt of $1.43 billion in its own stock and $245 million in cash from Canada's Dome Petroleum for Conoco's interest in Hudson's Bay Oil & Gas. The shocker in this deal was Dome Petroleum's being tendered about half of Conoco's stock after making a tender offer for just 20%. Since then, Conoco has said it turned down offers from other companies and was in negotiations of its own. □

Middle-sized chemical firms a healthy lot

More diverse than Top 50, second 50 also had higher return on sales; chemical sales run mostly from $200 million to $600 million

William F. Fallwell
C&EN, Washington

Despite the vigorous pace of chemical mergers and the problems forecast for smaller chemical producers in the 1980's, middle-sized chemical operations are continuing an overall healthy performance dispersed throughout U.S. manufacturing. In C&EN's second annual survey of the second Top 50 U.S. chemical companies—those ranking from 51 to 100 in terms of chemical sales—fewer than half show up in companies that call themselves chemical. The rest are tucked away in firms ranging from oil to aerospace to machinery to food and many others. More than a fourth are foreign-controlled.

In 1980, the second 50's chemical sales totaled $19 billion, up from $18 billion for a slightly different sample in 1979. The 1980 total is not even 20% of the $100 billion in chemical sales racked up by the 50 largest companies (C&EN, May 4, page 35).

The two C&EN surveys cover about 90% of the total U.S. process chemical sales in 1980 of $132 billion. The rest is mainly in companies not disclosing enough data for a good estimate of chemical sales. A small part is in sales of the many small companies below the cutoff point in the second 50 survey.

As indicated by the smaller total for sales of the second 50, the sales range in the middle-sized group is much narrower than in the Top 50. Whereas the larger 50 start with Du Pont's $10.3 billion in chemical sales and run to less than $1 billion, the second 50 start with Witco Chemical's $700 million and descend to less than $200 million. The great majority of the second 50 fall between $200 million and $600 million.

For the second 50, chemical operations tend to be a smaller part of the company than in the Top 50. Overall, the unweighted chemical sales average in the smaller group was 43% of total sales in 1980. The corresponding average for the Top 50 was 48%.

The second 50 chemical operations tend to have more profitable parent companies than do the Top 50. In 1980, the unweighted average profit margin on sales was 7.7% for the second 50 compared to 6.1% for the other group. Return on stockholders' equity also was higher for the second 50, averaging 18.2% compared to 16.5% for the Top 50.

By type of company, the second 50 show far more variety than do the Top 50, which are dominated by chemical and petroleum companies. Only nine of the Top 50 are in categories other than these two. By contrast, more than twice that number of second 50 companies are in different industries, covering a dozen distinctly different categories.

The foreign presence is also much stronger among the smaller firms than among the larger ones. Only five companies in the Top 50 are controlled from outside the U.S.—Shell Oil, Giba-Geigy, Mobay Chemical, BASF Wyandotte, and American Hoechst. These companies make up 7% of total chemical sales in the Top 50.

In the second 50, however, there are 13 companies controlled by non-U.S. parents. Dutch interest shows up in Akzona, National Starch, and North American Philips, Belgian in Soltex and American Petrofina, West German in Badische, French in Liquid Air, Canadian in Polysar and Texas-

Second 50 companies differ markedly from the Top 50

As in the first survey a year ago (C&EN, June 30, 1980, page 8), the second 50 chemical producers differ distinctly from the Top 50 (C&EN, May 4, page 40). The most striking contrast is in sheer size. The Top 50 had average chemical sales in 1980 of $2 billion, whereas for the next 50 largest, the average is just $380 million. In total chemical sales volume, the Top 50 tipped over $100 billion in 1980. The second 50 total came to $18.9 billion.

Another big difference between the two groups is the greater variety of companies in the second 50. Whereas basic and specialty chemical companies make up 23 of the Top 50, they account for only 14 of the second 50. Even more to the point, only eight oil and natural gas companies appear in the second 50, compared to 14 in the Top 50.

As in many other surveys, the smaller companies are more profitable than the larger chemical producers—by 1.6 percentage points or one fourth in 1980. However, they have less of a stake in chemicals than do the larger producers.

	Second 50		Top 50	
	1980	1979	1980	1979
CHEMICAL SALES				
Total ($ billions)	$18.9	$18.2	$100.0	$90.2
Average size ($ millions)	$380	$360	$2.0	$1.8
Average annual growth[a]	16%	22%	12%	26%
Average % of total company sales[a]	43%	37%	48%	49%
PARENT COMPANY TYPE				
Basic and specialty chemical	14	19	23	26
Agricultural chemical, including cooperatives	5	6	4	2
Petroleum, including natural gas	8	8	14	14
Drug	4	4	0	0
Other	19	13	9	8
PARENT COMPANY PROFITABILITY				
Average profit margin[a]	7.7%	7.5%	6.1%	6.1%
Average return on stockholders' equity[a]	18.2%	17.1%	16.5%	16.5%

[a] Unweighted.

Fewer than half of the second Top 50 are chemical companies

Rank 1980	Company	Chemical sales 1980 ($ millions)	Change from 1979	Total sales 1980 ($ millions)	Chemical sales as % of total sales	Industry type	TOTAL COMPANY: Net income ($ millions)	Profit margin[a] Per cent 1980	Profit margin[a] Rank 1980	Return on stockholders' equity[b] Per cent 1980	Return on stockholders' equity[b] Rank 1980
51	Witco Chemical	$705	26%	$1,175	60%	Specialty chemicals	$ 41.0	3.5%	34	15.4%	30
52	Texasgulf	663	43	1,090	61	Mineral chemicals	325.6	29.9	1	27.9	5
53	Esmark	627[c]	25	2,956	21	Food	59.5	2.0	43	10.3	42
54	Pennwalt	602	7	1,189	51	Basic chemicals	43.3	3.6	33	11.0	40
55	Koppers	577[c]	4	1,929	30	Diversified chemicals	55.0	2.9	39	8.8	43
56	Akzona	575	0	1,054	55	Basic chemicals	4.9	0.5	46	1.5	45
57	Cities Service	557	6	7,786	7	Petroleum	477.5	6.1	25	18.5	22
58	NL Industries	552	3	2,118	26	Petroleum services	167.7	7.9	20	18.6	21
59	Freeport-McMoRan	527	31	664	79	Mineral chemicals	147.4	22.2	2	29.6	3
60	Aluminum Co. of America	523[c]	21	5,196	10	Nonferrous metals	469.9	9.0	15	16.0	29
61	Eli Lilly	518	10	2,559	20	Drugs	342.0	13.4	6	19.7	16
62	Kerr-McGee	501	19	3,478	14	Petroleum	182.2	5.2	28	13.6	36
63	Kaiser Aluminum	490	17	3,222	13	Nonferrous metals	247.6	7.7	21	17.5	25
64	El Paso	489	47	3,543	14	Natural gas	108.9[d]	3.1	38	25.0	6
65	Uniroyal	488	9	2,299	21	Tires	−7.8	•	—	•	—
66	Standard Oil (Ohio)	476	19	11,023	4	Petroleum	1,811.2	16.4	3	39.7	1
67	Badische	453	14	453	100	Basic chemicals	16.9	3.7	31	11.1	39
68	International Flavors	448	10	448	100	Specialty chemicals	63.2	14.1	5	20.0	14
69	Merck	448[c]	18	2,734	16	Drugs	415.4	15.2	4	22.3	10
70	Cabot	441	14	1,404	31	Specialty metals	152.7	10.9	10	29.4	4
71	Airco	420	29	1,011	42	Basic chemicals	na	na	—	na	—
72	Pfizer	416	8	3,029	14	Drugs	254.8	8.4	17	16.2	27
73	Internorth	360	10	3,038	12	Natural gas	211.7	7.0	24	18.0	24
74	National Starch	359	17	552	65	Specialty chemicals	33.4	6.1	25	14.2	35
75	Soltex	350[f]	na	350	100	Basic chemicals	na	na	—	na	—
76	North American Philips	345[c]	5	2,658	13	Electrical products	74.5	2.8	41	19.2	18
77	Mississippi Chemical	344	30	344	100	Farm cooperative	44.2[g]	12.9	9	30.3	2
78	Upjohn	326	8	1,761	19	Drugs	170.4	9.7	13	19.7	16
79	American Petrofina	317	7	2,099	15	Petroleum	104.3	5.0	29	20.8	13
80	Liquid Air	312	15	408	76	Basic chemicals	29.4	7.2	22	13.2	37
81	Baker Industries	295	30	295	100	Agricultural chemicals	28.9	9.8	11	24.1	7
82	Terra Chemicals	286[c]	18	299	96	Agricultural chemicals	10.3	3.4	35	18.7	19
83	Thiokol	285	10	675	42	Aerospace	32.4	4.8	30	14.3	34
84	GAF	284	8	677	42	Diversified chemicals	10.3[d]	1.5	44	8.4	44
85	Vulcan Materials	284	17	754	38	Nonmetallic minerals	69.9	9.3	14	19.9	15
86	Emhart	281	9	1,803	16	Machinery	67.0	3.7	31	14.8	32
87	Polysar	264	na	264	100	Basic chemicals	na	na	—	na	—
88	Martin Marietta	258	6	2,619	10	Aerospace	188.1	7.2	22	17.1	26
89	SCM	247[c]	12	1,892	13	Paint	53.9	2.9	39	11.8	38
90	H. B. Fuller	238	13	297	80	Specialty chemicals	9.7	3.3	37	15.0	31
91	Petrolite	233	35	254	92	Specialty chemicals	24.9	9.8	11	22.2	11
92	First Mississippi	221	41	243	91	Agricultural chemicals	21.2	8.7	16	18.7	19
93	Loctite	199	23	199	100	Specialty chemicals	25.9	13.0	8	22.6	9
94	Big Three Industries	199	15	659	30	Petroleum services	86.6	13.1	7	18.3	23
95	Engelhard	195[c]	10	3,200	6	Specialty metals	66.0	2.1	42	na	—
96	Houston Natural Gas	194	14	2,358	8	Natural gas	196.7	8.3	19	22.9	8
97	Northwest Industries	193	0	2,876	7	Conglomerate	155.4	5.4	27	16.2	27
98	Getty Oil	168	14	10,437	2	Petroleum	871.9	8.4	17	21.0	12
99	Agway	166	9	2,657	6	Farm cooperative	39.2[g]	1.5	44	14.8	32
100	Stepan Chemical	158	9	158	100	Specialty chemicals	5.4	3.4	35	10.7	41

a Net income as percentage of net sales. b Net income as percentage of year-end stockholders' equity. c Chemical sales include significant amounts of nonchemical products such as fabricated plastics, coatings, metals, drugs, and the like. d Net income excludes nonrecurring charges—El Paso $411.9 million and GAF $243.8 million. e Deficit. f C&EN estimate. g Net income represents patronage refunds (pretax) plus net earnings or net margin. na = not available.

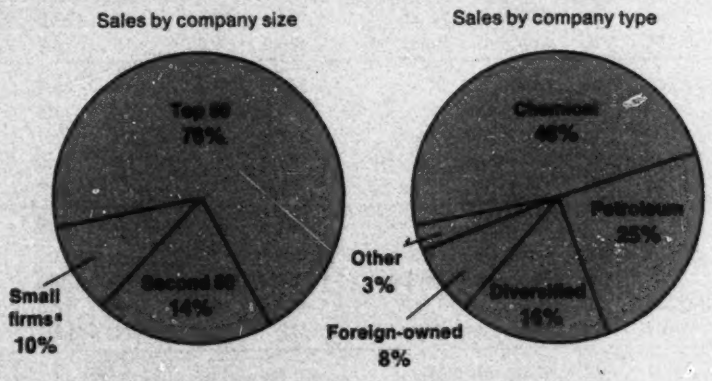
The real U.S. chemical industry

How big is the U.S. chemical industry? That should be an easy one, but it isn't, and never was. Now the answer is pretty well cleared up.

The trouble is that the chemical industry, unlike many other manufacturing groups, is an amorphous beast. Some companies called chemical have most of their sales in nonchemical products. And many companies called something else have large blocks of sales in chemicals.

Total sales of U.S.-produced chemicals in 1980 amounted to about $132 billion. Of this, the Top 50 accounted for 76%; the second 50, 14%; and the rest, 10%.

Or, by company type, the breakdown is 48% of total sales from chemical companies, 25% from petroleum companies, 16% from other diversified manufacturers, 8% from foreign-controlled companies, and 3% from other, mostly very small, firms.



Total 1980 U.S. chemical sales = $132 billion

a And firms not disclosing chemical sales.

It used to be a fair assumption that the nonchemical sales of chemical companies just about equaled chemical sales of nonchemical companies. In other words, official sales or shipments figures from the government for the chemical industry were a pretty good measure of real chemical sales.

But no longer. C&EN's Top 50 and second 50 surveys of real chemical sales by various producers, plus estimates on chemical sales of the remaining smaller or more obscure chemical producers, show a somewhat different picture.

By contrast, the Commerce Department lists shipments of U.S. chemicals and allied products at $162 billion for 1980. This is now considerably greater than the real total of chemical sales.

In other words, the real chemical industry is now only half in the official core group of basic, specialty, agricultural, and mineral chemical companies. Of the rest, by far the most important part is in the petroleum industry. The final block is spread far and wide in food, metals, machinery, aerospace, wood products, photographic, electrical, drug, and other companies.

gulf, British in Airco and Standard Oil (Ohio), and South African in Terra Chemicals International and Engelhard. These U.S. operations account for 23% of the total chemical sales of the second 50.

The foreign part of both the Top 50 and second 50 is understated, since foreign-controlled operations are prominent among chemical producers not divulging adequate data to make these listings. For example, the Top 50 list might very well include ICI Americas, whose chemical sales are probably more than $600 million. In the second 50 list, several foreign-owned U.S. operations are missing—Sandoz, Henkel, Hoffmann-La Roche, U.S. Borax, and Rhône-Poulenc.

The ranks of missing companies also include U.S. chemical operations buried deep in secretive parent firms. Companies not giving a clear enough breakdown of process chemical sales include Goodyear, 3M, Firestone, General Tire, Procter & Gamble, General Electric, Sun, Avtex, Simplot, Beatrice Foods, and Dart & Kraft.

All told, these elusive chemical operations came to roughly $7 billion in 1980 sales, based on occasional estimates from consultants or companies themselves on their chemical sales. That includes operations both U.S. and foreign-owned in both the Top 50 and second 50.

In the second 50, C&EN aims to include mainly process chemical sales. By standard industry categories, this would cover basic organics and inorganics, downstream intermediates, polymers, fertilizers and other agricultural chemicals, and some highly synthesized specialties such as water treatment chemicals and lubricants. Although not always possible, these sales typically exclude purely fabricated or formulated products such as many finished plastics and coatings. The listing also excludes related chemical categories such as drugs, detergents, and cosmetics, even though many of these are chemically synthesized products.

The data are still approximate, since many companies combine chemical and other sales for organizational reasons. Frequently, the nonchemical products are made with captively produced chemicals. Sometimes, chemical sales include equipment needed with the chemicals, such as revenues derived from welding equipment for industrial gases.

However, some companies' sales breakdowns also can hide chemical sales included in other categories. A good example is Pfizer, whose materials science segment includes substantial sales of lime and iron oxide pigments.

Another example has been Witco Chemical, whose sales labeled petroleum actually include a lot of chemicals such as surfactants. Fortunately, Witco has given C&EN a special breakdown of chemical sales this year to include chemicals in the petroleum part of the company. For this reason, Witco's chemical sales slightly overlap the end of the chemical sales range in the Top 50.

Two other companies also slightly overlap the Top 50—Texasgulf and Esmark. Texasgulf's chemical sales are in the gray area to some analysts, since they include a lot of sulfur, which is mined as the element. However, the second 50 includes Texasgulf, since the company uses much of its sulfur to produce phosphoric acids and phosphate fertilizer.

Esmark's chemical sales do not really overlap the Top 50, since they include some distinctly nonchemical items such as dental equipment and engineered products. However, the company provides no further breakdown and certainly should be on the second 50 list. □

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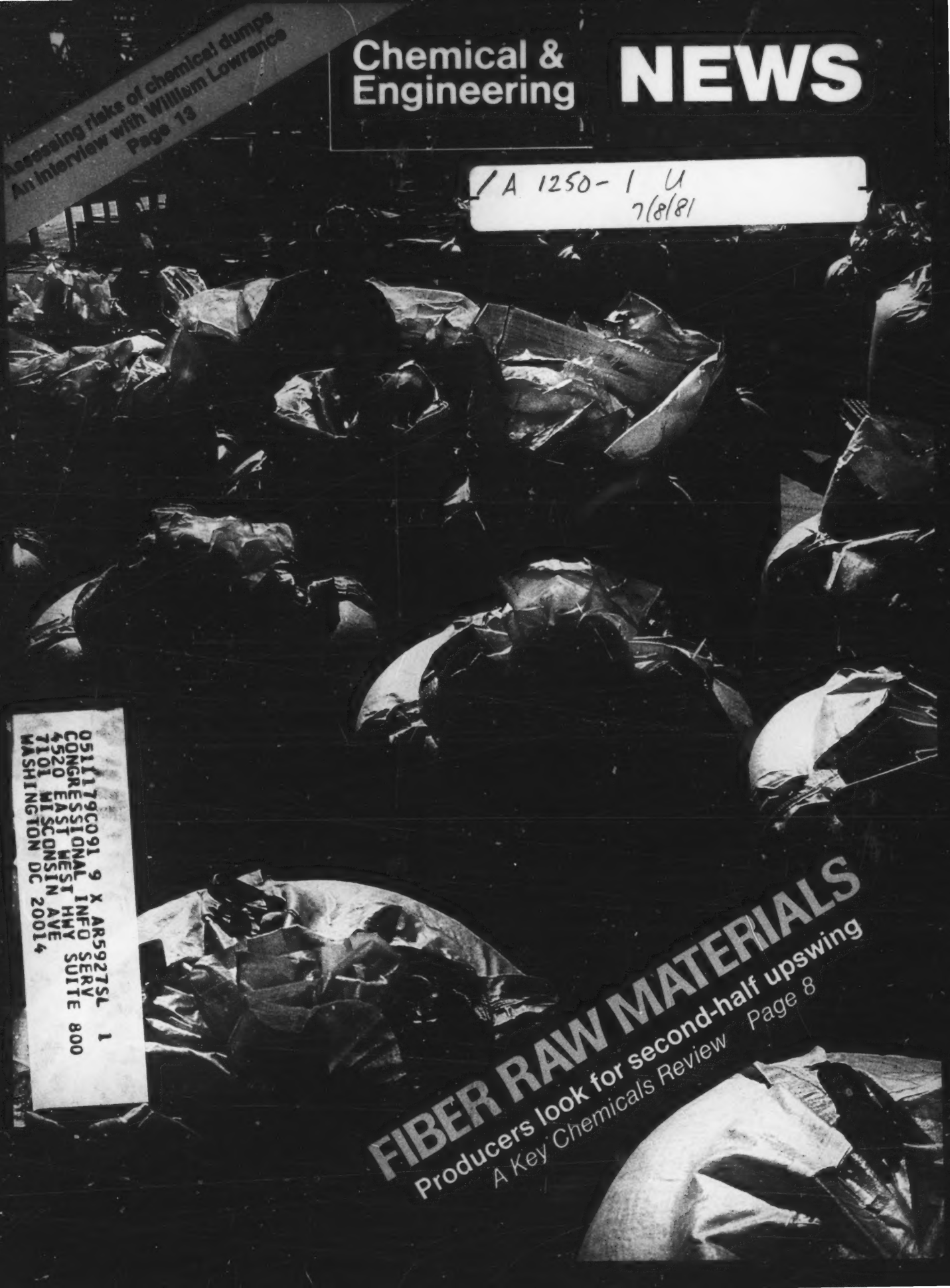

FIBER RAW MATERIALS

Producers look for second-half upswing

A Key Chemicals Review Page 8

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Chemical & Engineering NEWS

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Fiber raw materials lag fibers in recovery

Although polyester and nylon are bouncing back this year, their intermediates—DMT/PTA, ethylene oxide, and cyclohexane—are struggling

If the top synthetic fibers, polyester and nylon, seem finally to be past eight years in the woods and not far from the business sun, wouldn't the main organic chemicals going into fibers—dimethyl terephthalate (DMT)/purified terephthalic acid (PTA), ethylene oxide, and cyclohexane—also have better days ahead? A logical answer might be yes. But considering the realities of 1981, the better answer is more like "not necessarily."

One of the ironies of the new business cycle, following the recession in 1980, is that these two closely tied product groups face considerably different fortunes in 1981 and probably beyond. This time around, the intermediates have much farther to go to reach good business health than do the fibers.

Two of the best barometers of the business climate, production and plant capacity use, offer pointed evidence of the disparity this year between intermediates and fibers. In production, polyester and nylon already are fully recovered from last year's recession. They are reacning for new expansion. But the three intermediates, business sources say, will be hard pressed to regain 1979 production levels totaling 13 billion lb even with a good second half in 1981.

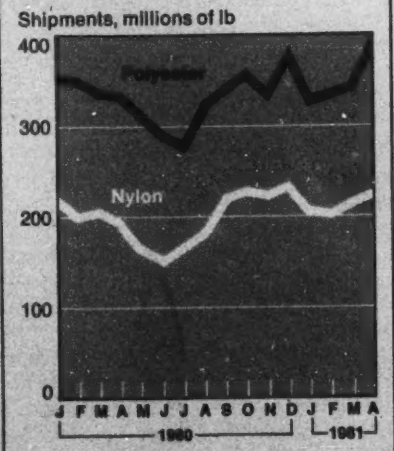
The key to a successful catch-up to 1979 production levels in 1981 will be successful recovery of DMT/PTA, whose downstream use in polyester is coming up faster than is the nylon outlet for cyclohexane. The consensus of industry sources now is that DMT/PTA has a chance to make full recovery, reaching output of 5.5 billion lb. This would equal expected 1981 production of 5.5 billion lb for ethylene oxide, which is rising a little this year after staying about flat in 1980. The combination of these two intermediates would about offset an expected shortfall of 200 million lb in cyclohexane production in 1981 from its 1979 output of 2.3 billion lb. Even so, these intermediates would be at least half a year behind the recovery pace in fibers, which already has reached the level of prerecession production.

In capacity use, the various types of polyester and nylon already have reached fairly high levels, in the 80's and 90's as a percentage of nameplate totals by C&EN's latest capacity use survey (C&EN, May 25, page 13). But the intermediates still are mired about 20 percentage points below.

The irony continues in plant expansion plans. There aren't any big ones in fibers, whose producers are still a bit shocked from the long glut and shakeout in the mid- and late 1970's. By contrast, in the intermediates, Du Pont has a new cyclohexane plant coming on stream in 1983 near Corpus Christi, Tex. And ethylene oxide capacity continues to rise with slow catalyst changes. Beyond this, Dow Chemical plans a new block of ethylene oxide capacity at Plaquemine, La., in 1983.

Even with the continued weak profitability promised by the intermediates' plant capacity situation, business volume in the intermediates is quite large, about two thirds of the total production value of the two downstream fibers. C&EN estimates the total production value of the intermediates at $5.1 billion in 1981, including quantities sold or converted to other products not in the fiber industry. The gain in value this year will be about $1 billion from 1980 or nearly 25%.

End-product fibers are expanding again



Source: Textile Economics Bureau

Both inflation and physical volume gains contribute to this value increase. Of the two factors, inflation is more difficult to nail down. Cyclohexane, for example, follows raw material benzene prices closely except in times, unlike the present, of cyclohexane shortage. As a result, its price fluctuates more than prices of the other materials.

A leading basic influence on cyclohexane and DMT/PTA prices is the vagaries of fuel operations at oil refineries. Through precursor benzene and *p*-xylene, respectively, the intermediates feel the competing pull of octane-booster demand for gasoline. In general, when no-lead, high-octane gasoline supplies are tight, these aromatic derivatives are more expensive. This cost pressure on the intermediates has been relieved a bit this spring by weakness in gasoline and in spot benzene prices.

Even so, fiber intermediates will need a strong upward shift in pure business volume to lift profitability. For the next two years, there may be a ceiling on such growth from the very limitations in fiber production capacity. Polyester and nylon don't really have much room to grow without new investment, which will take at least two years to come on stream.

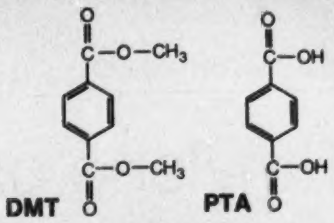
Some relief conceivably could come from exports of the intermediates, but this won't be large. For DMT/PTA and ethylene oxide, exports are low in any case relative to production. DMT/PTA exports may rise a little this year. Cyclohexane exports are more important, about 14% of production this year. However, cyclohexane exports have had a hard time recently, and are dropping for the second straight year. Industry sources say, however, that the decline might level off in 1981.

For details on the immediate outlook for the three fiber intermediates, see the following pages.

Bruce Greek, Houston, and William Fallwell, Washington

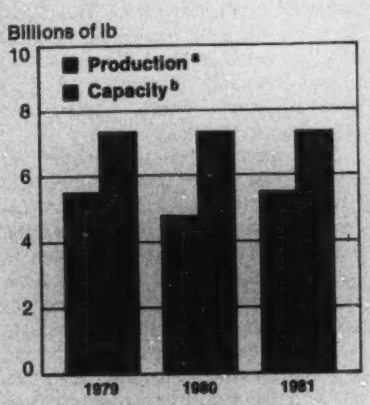
Key Chemicals

DMT/PTA



- ***Demand recovering***
- ***Capacity unchanged***
- ***Prices up a bit***

PRODUCTION/CAPACITY



a Total for both DMT and PTA. b First quarter.

HOW MADE

Oxidation of p-xylene and concurrent esterification to make DMT; oxidation of p-xylene to make PTA

MAJOR DERIVATIVES

Polyethylene terephthalate 95%, polybutylene terephthalate 5%

MAJOR END USES

Fibers 85%, films 5%, bottles and other fabricated forms 5%

FOREIGN TRADE

Exports—to exceed 400 million lb in 1981, imports—negligible

PRICES

About 36 cents a lb for DMT and 38 cents a lb for PTA

COMMERCIAL VALUE

$2 billion for total production, 1981

Recovery is the key word in 1981 for dimethyl terephthalate (DMT) and purified terephthalic acid (PTA). Given a reasonably strong U.S. economy for the rest of the year, combined production of DMT and PTA could match 1979 at 5.5 billion lb. This would be 15% above estimated 1980 production of 4.8 billion lb, which reflected recession ravages in the polyester fiber market.

Some industry sources are a bit less optimistic about 1981 fortunes of DMT and PTA. They expect just a 10% increase in production.

After 1981, assuming no important business slowdown in 1982, production would continue to grow but more slowly, rising at least above 1979's 5.5 billion lb for combined production. Even conservative growth from 5.2 billion lb to 5.5 billion lb for 1982 would be toward the high end of these materials' projected growth range for the 1980's. Depending on the degree of optimism, industry sources put this pace at 3 to 8% per year.

Much difference of opinion exists on actual production totals of DMT and PTA. The relatively high estimates of production reported by the International Trade Commission suggest higher capacity utilization rates than producers actually experience. Many industry sources calculate DMT/PTA production from estimates of polyester fiber, film, and resin production and estimates of DMT/PTA exports. Such calculations naturally lose some accuracy because of the varying quality of the scattered data, but analysts believe the results are more accurate than the government's data.

By such industry estimates, production of DMT/PTA has averaged 5.5 billion lb a year or a bit less for the past four years. Hence, current nameplate plant capacity of 7.3 billion lb a year certainly is adequate. The resulting average plant operating rate of 75% or less provides little incentive for capacity additions. To go by the high rates of plant operation in the early 1970's as examples, production of 6.5 billion lb or so would be needed now before companies would give serious thought to additional capacity. This might be true even if a potential supply pinch looms sometime in the future. Three years at least may then be needed before additional capacity will be committed for DMT or PTA, assuming demand growth averages 5% or so annually.

To provide this kind of growth for DMT/PTA, polyester fibers will have to stay on the growth trail. Although fibers' share of DMT/PTA consumption is falling to 80 to 85% of the total DMT/PTA market, the sheer size of this share offsets the larger growth rate for DMT/PTA's application in bottle resins.

Polyester film also has a higher growth rate than do fibers, but again its base is much smaller. This year film, at 8% of total polyester consumption, will exceed bottles' share. However, this could be the last year that film will keep second place because of bottles' high growth rate.

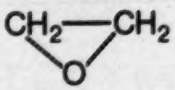
Polyester resins' use in nonreturnable bottles gets inordinate attention as the fast growing use of the future for DMT/PTA. There's little doubt that bottles, especially soft drink bottles, have such potential, provided bottle manufacturing technology and costs improve and no major political push takes hold against nonreturnable containers.

Still, bottles' growth may be in steps. Currently, bottles are coming out of a fast-growth period, having conquered most of the market for large-sized soft drink bottles, mainly the 2-liter type.

Proponents of continued growth in bottles once held that the next area to be conquered would be the 1-liter bottle. Now this seems less likely. Bottle resin marketers have turned their attention instead toward the half-liter size. Their hope is to replace the 16-oz glass bottle or metal can and possibly, but less likely, the 12-oz can.

Some resin development still may be needed for this campaign, but apparently most of the current development work is going to improve bottle-making machines. Perhaps in another five years, the smaller bottles could provide a jump in resin use similar to the spurt in use for large bottles, which grew from virtually nothing to 350 million lb.

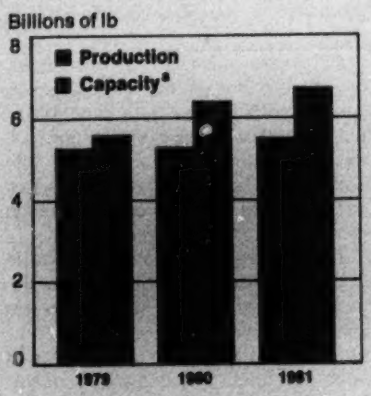
In the meantime, producers of DMT/PTA will have to look to fibers and a bit to film to boost their product. Polyester fibers are indeed improving, but whether the gain will be enough to bring 1981 DMT/PTA production back to the level of 1979, producers aren't yet sure.



Ethylene oxide

- ***Demand inching up***
- ***Capacity up slightly***
- ***Prices soft***

PRODUCTION/CAPACITY



a First quarter. Note: 1981 capacity figure excludes about 0.5 billion lb of annual capacity now indefinitely shut down.

HOW MADE

Vapor-phase oxidation of ethylene with oxygen or air

MAJOR DERIVATIVES

Ethylene glycol 80%, ethoxylates 10%, glycol ethers 10%

MAJOR END USES

Polyester fibers and films 30%, antifreeze 25%, surfactants 10%

FOREIGN TRADE

Exports—small, probably under 100 million lb, and significantly larger for derivatives; imports—negligible

PRICES

Posted prices 44 to 45 cents a lb

COMMERCIAL VALUE

$2.5 billion for total production, 1981

U.S. demand for ethylene oxide this year is improving from last year, but just slightly. Although the outlook indicates another poor year, 1981 still will be better than 1980. Last year, production apparently increased less than 25 million lb from 1979 to a total of about 5.3 billion lb, according to the International Trade Commission.

In 1981, assuming some improvement in demand in the third and fourth quarters, production of ethylene oxide could reach 5.5 billion lb. This would be up 3.8% over 1980.

Absolutely no problem exists in filling 1981 demand for ethylene oxide. Nameplate plant capacity as the year began exceeded 6.7 billion lb, and more is on the way. In addition to 500 million lb of capacity which ICI Americas will be starting up later this year, perhaps 200 million to 300 million lb of additional capacity will be added through debottlenecking of existing plants. On the side, more than 200 million lb of capacity at Calcasieu Chemical went into indefinite shutdown status in January. This capacity could be restarted if needed on relatively short notice.

The result will be a plant operating rate for 1981 of no more than 82% of first-quarter capacity. If 1981 output of ethylene oxide is 100 million lb lower than is now estimated and if additional nameplate capacity of 100 million lb is counted at Calcasieu, ICI Americas, and others, the operating rate drops to 80% or a bit less.

Even these operating rates would represent a considerable improvement from ethylene oxide's pace earlier in the year. In C&EN's latest capacity use survey (C&EN, May 25, page 14), the first-quarter rate was 65%, down from 84% a year earlier.

These operating rates are in sharp contrast to a decade ago, when they exceeded 100% of nameplate capacity in 1969 and 1970. Those rates led to a near doubling of capacity in the 1970's and to the present less-than-desirable operating conditions.

The current low operating rate brings the usual corollary, downward pressure on prices. Some increase in ethylene oxide prices has occurred, mainly as producers passed through cost increases, especially for raw material ethylene. However, industry sources indicate that a differential continues between posted and actual contract prices for ethylene oxide. Typically, before any current price increases go into effect, the differential is about 4 to 5 cents a lb.

Also figuring in ethylene oxide's price problems are the usual demand and price problems of its major derivatives, particularly ethylene glycol. The glycol accounts for a bit more than 60% of ethylene oxide demand. About 90% of glycol demand comes from two uses—polyester fibers, bottles, and films; and antifreeze.

Polyesters are showing some life again in their largest outlet, textiles, and have recovered fully from the 1980 recession. The question is, for how long. Fashion and competition from other fibers, both natural and synthetic, have often upset an improving trend for polyester fibers. As a result, forecasts for the life expectancy of this upswing in polyester fibers are difficult to get, although fiber industry sources are more hopeful than in a long time.

Polyester bottle material has been in high growth from a small base. Nonethylene glycols and other materials appear to be cutting into this growth for ethylene oxide. However, more development work by both producers and consumers of bottle polyester could keep this nonfiber market booming and bring ethylene oxide along with it. Right now, hard and fast forecasts for these uses are as rare as those for improved long-term fiber demand.

Antifreeze's problem is an old story—inventory buildup due to a warm winter and delay in radiator care by financially pressed car owners. Even without this temporary jam, growth in demand for ethylene oxide for glycol antifreeze is forecast to be just 1% a year for some time as cars shift to smaller-sized engines and radiators.

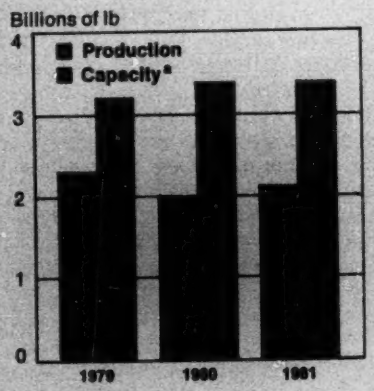
Other uses of ethylene oxide are mostly specialty in nature. The ethoxylates, ethanolamines, ethers, and other glycols all could have growth rates above that of ethylene glycol. However, their markets are so small that the net effect on oxide also would be small.

On balance, 1981 will be another year of struggle for ethylene oxide during which downward pressure on prices will continue from overcapacity.

Cyclohexane

- ***Demand to rise***
- ***Capacity flat***
- ***Price variable***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Catalytic hydrogenation of benzene; recovery from natural gas condensates

MAJOR DERIVATIVES

Adipic acid 65%, caprolactam 30%

MAJOR END USES

Nylon 66, 60%; nylon 6, 30%

FOREIGN TRADE

Exports—decline slowing to about 300 million lb; imports—negligible

PRICES

$1.90 per gal posted; follows benzene price

COMMERCIAL VALUE

$600 million for total production, 1981

U.S. production of cyclohexane in 1981 likely will reach 2.1 billion lb or about 322 million gal. This level would be about 5% over 1980 production but still 10% below that of 1979. In effect, cyclohexane production will not be growing for two years.

The reason for this dull performance continues to be the same as in several other major-volume organics, a troubled single end use or one dominant end use. For cyclohexane, everything depends on nylon. All nonnylon uses of cyclohexane together in 1981 probably will take less than 10% of production. Put another way, uses that do not involve intermediate adipic acid or caprolactam will be about 1% of production. Such applications are mainly as a solvent or raw material for small-volume specialty chemicals.

The nylon uses of cyclohexane currently are split about two to one in terms of adipic acid and caprolactam intermediates, which go, respectively, to nylon 66 and nylon 6. Some relatively small quantities of cyclohexane are used to make hexamethylenediamine (HMDA), the other component of nylon 66. Most HMDA, however, is made from other raw materials such as butadiene. Not all caprolactam is made from cyclohexane; phenol accounts for nearly half of caprolactam as the alternative raw material.

Although both kinds of nylon are used to make engineering plastics, fiber uses dominate cyclohexane's end-use pattern.

Among these fiber uses, rugs and carpets take the largest share by far. In effect then, the outlook for cyclohexane depends largely on how well sales go for rugs and carpets. The 1980 recession hit these end products hard, so nylon producers reduced output. Their lowered raw material needs led to a 15% falloff in demand for cyclohexane.

As the recession eased and pipelines of nylon fiber products needed refilling, producers looked for more cyclohexane. Production improved during the first quarter to a rate of 2.1 billion lb a year. This rate apparently has fallen off during the second quarter, following the usual seasonal pattern. The normal pickup would begin at the end of this month. Outlook for the fourth quarter depends somewhat on the economy. Some producers expect a slow, steady increase buoyed by commercial building and renovation.

Nylon carpet dominates in commercial carpet use because it withstands wear better than most other carpet fibers, though at a somewhat higher cost. This "best value" concept accounts for nylon's dominance of the carpet fiber field with about 80% of the total.

Nylon's importance in commercial carpet has helped nylon withstand some of the effects of the slowdown this past year in demand for chemicals. The impact of the lower housing construction has hit polyester fibers harder than it has hit nylon fibers, since polyester overshadows nylon in residential carpets. This, despite nylon fibers' being more concentrated in a single market than is polyester fiber.

Currently, improvement in demand for cyclohexane is expected to be slow. A return to production over 2.3 billion lb a year might have to wait beyond 1982. This means that plant capacity use will remain relatively low, not much more than 60%.

Plant capacity will not expand much if any until 1983, when a new Du Pont unit of 50 million gal a year capacity or about 330 million lb a year is expected on stream near Corpus Christi, Tex. One raw material for this plant is expected to be hydrogen produced in a nearby chlor-alkali unit and now used for fuel. For the other raw material, Du Pont is expected to be a large buyer of benzene. The new cyclohexane plant still will supply only part of Du Pont's cyclohexane needs.

The new unit's use of by-product hydrogen highlights a growing problem for cyclohexane producers—demand for their hydrogen supply by other uses. Since most cyclohexane is produced at oil refineries, it must compete with refining uses for hydrogen. These uses, notably in processing lower-quality crude oils through hydrogenation processes, tend to make nameplate capacity for cyclohexane less meaningful unless hydrogen availability in the future is secure.

For 1981, however, cyclohexane faces ample capacity, a modest improvement in demand, and price action following variable raw material benzene.

NOTE

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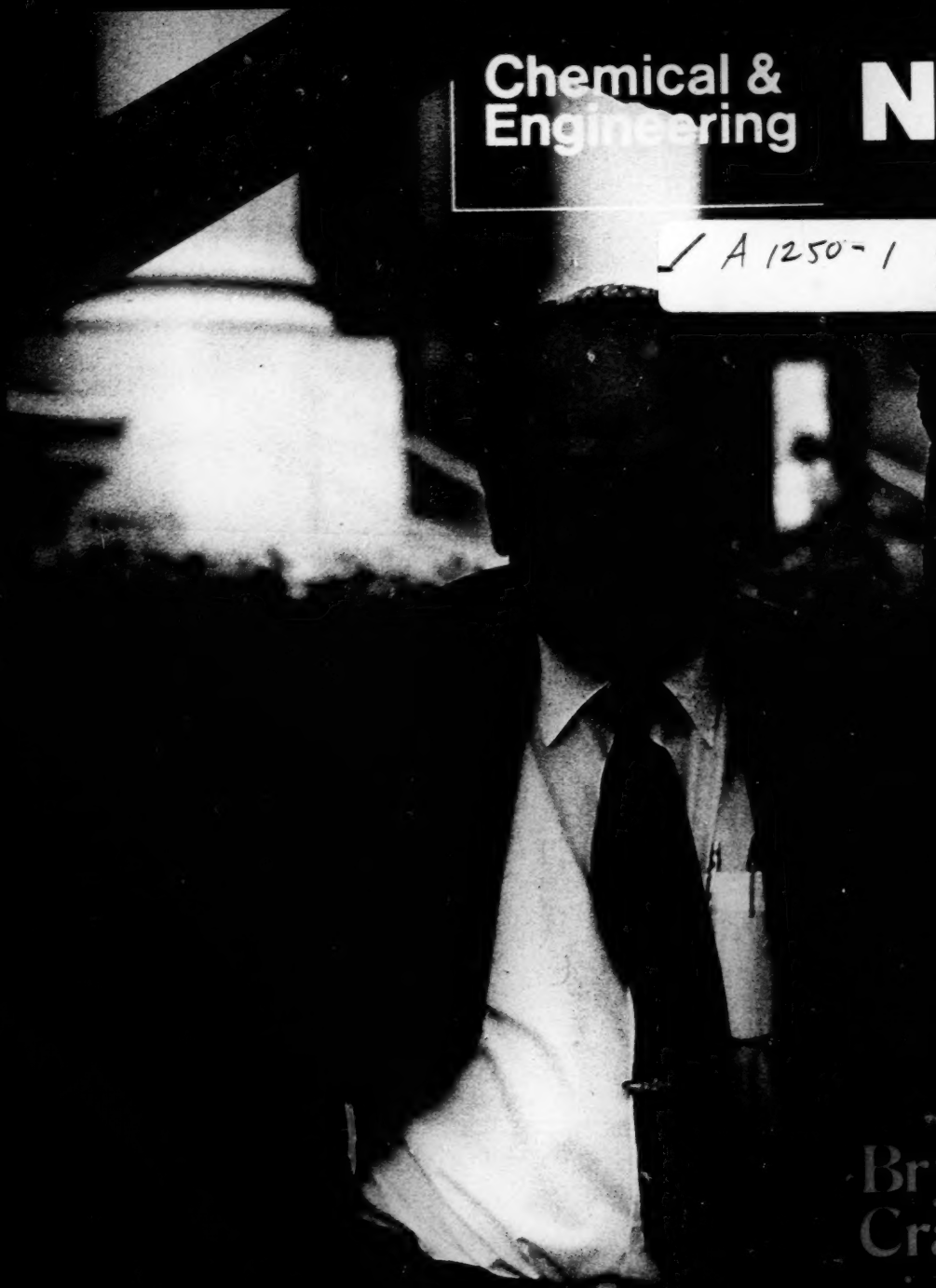

Bryce Crawford wins 1982 Priestley Medal

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News of the Week

- ***If the Conoco acquisition goes through,*** *Du Pont will have substantial oil and gas interests, which may slow its development of specialty chemicals.* **Page 6**
- ***Acetic anhydride spill*** *from freight train derailment causes evacuation of some residents of Wisconsin town.* **Page 7**
- ***Executive order*** *giving OMB power over federal rule-making activities may be illegal or unconstitutional, says Congressional Research Service.* **Page 7**

Business

- ***Plastics additives*** *show signs of improvement this year following poor showing in 1980, as plastics production responds to increased demand.* **Page 9**

International

- ***Japanese chemical industry,*** *struggling to recover since hitting bottom last year, is in for a long haul unless Japan's economy improves dramatically.* **Page 11**

Government

- ***R&D funding policy*** *of Reagan Administration outlined at colloquium sponsored by the American Association for the Advancement of Science.* **Page 13**

Science

- ***Controversial theory*** *that enough hydrocarbon fuel to last millennia was trapped in Earth's interior as it formed is being tested by monitoring escaping gases.* **Page 17**

Priestley Medal

- ***1982 Priestley medalist Bryce Crawford has*** *contributed much to chemistry as teacher, molecular spectroscopist, editor, and through active service in ACS.* **Page 18**

Books

- ***"An Imagined World"*** *by June Goodfield relates a realistic day-by-day account of scientific research today.* **Page 21**

ACS News

- ***ACS Board sets prices*** *for CAS publications, services; introduces reduced price for CA in least-developed nations.* **Page 24**
- ***Society honors high school student winners*** *of science fair with cash awards and ACS journal subscriptions.* **Page 25**

Final Program

- ***Technical sessions, special events,*** *tours and plant trips, preregistration coupons provided for New York meeting.* **Page 28**

Plastics additives head for turnaround

Demand for additives is tied closely to plastics output, which shows signs of moving back up this year following 9.2% falloff in 1980

William J. Storck
C&EN, New York

U.S. producers of plastics additives, although not exactly jumping for joy, are happier this year than they were in 1980. The reason is that plastics production is recovering from the traumatic time it had last year—and as plastics go, so go plastics additives.

The best news is that production of polyvinyl chloride, the biggest additives market, though not yet spectacular, is showing signs of improvement this year. Thus far, for the first four months of 1981, production of PVC is off 3.4% from 1980 levels according to data on plastics production published by the Society of the Plastics Industry's Committee on Resin Statistics as compiled by Ernst & Whinney, New York City-based accounting firm. However, for April alone, PVC production was up 13.2% from April 1980.

PVC demand is doing even better than production. Although sales and captive use are up only 1.9% through April, the April figure alone is up more than 28% from the same month a year ago.

It is easy to see the dependence of the additives market on plastics when one compares the results of the two businesses between 1979 and 1980. In 1980, plastic production fell 9.2% from 1979 and demand dropped 8.4%. At the same time, plastics additives demand fell 8.5%, according to figures published by Charles H. Kline & Co., a chemical consulting firm.

The drop, according to the Kline figures, was led by lubricants, which fell 17.8% from 1979. This was followed by some rather small-volume additives such as ultraviolet stabilizers, down 12.9%, and antioxidants, down 10.6%. Heat stabilizer demand was off 9.9% and plasticizers demand was off 9.7%. Demand for colorants was down 9.4% and that for chemical blowing agents 6.9%. Only two categories showed increased demand in 1980 from 1979. Fire retardant demand grew 5.3%, and demand for much smaller-volume organic peroxides grew 7.7%.

Plastics additives at a glance

Market: [illegible] billion lb; 1980 value about $2.0 billion

Growth: 4 to 5% per year for the next five years; will follow plastics growth closely

Producers: Diverse industry; however, certain companies are makers in additive types

Foreign trade: Negligible; technical service requirements bar both exports and imports

Producers of plastics additives, however, expect demand to return to more normal growth rates this year or next. More normal means growth of 5 to 6% per year. This corresponds to an average growth rate of about 6% per year for plastics.

There are a couple of reasons why growth of additives is generally slower than that of their end-use plastics. First is that growth of PVC, which takes by far the largest bulk of additives, is expected to be slower than for many of the other plastics.

The second is that the amount of additives used per 100 lb of resin is dropping as producers try to develop more efficient materials. The need for more efficient materials comes because of formulators' desire to lower costs and, in some cases, the need to lower concentrations of toxic materials in the additives because of worker safety. The safety factor is especially of concern for lead and barium-cadmium heat stabilizers.

The effect of the more efficient materials is shown in a study of the U.S. plastics additives market made by Predicasts, a Cleveland-based market consulting firm.

Predicasts says that although 0.19 lb of additives was used per pound of resin in 1979, this use will decline to 0.18 lb in 1995. This decline may seem minuscule, but Predicasts includes fillers and extenders and reinforcing fibers in its study. The consulting group thinks that, in these areas, the use per pound of resin will increase as formulators try to reduce costs. Thus, the other, more chemical, additives taken together will decrease as a percentage of the total product even more than the Predicasts study suggests.

The additives market as a consequence is not growing so much as producers would like, considering the specialty nature of their product, and the large number of producers will make it increasingly competitive. There are more than 30 companies in the U.S. making just plasticizers. Add to this the companies that make other materials used in plastic processing and the list becomes very large.

One of the most interesting things about the plastics additives industry is that plastics resin producers, by and large, are not makers of additives. (An exception is that many resin makers produce plasticizers.) There seem to be several explanations for this: the high cost of entry into the market, the specialty nature of the business compared to the commodity marketing mentality of most resin producers, and resin producers' simply missing the boat when they could have gotten into the market.

The result of the splits among the additives maker, resin producer, and formulator has guaranteed high employment for technical service personnel.

Since additives are tailored largely to the specific resin for which they are used, the need for technical service is great. Manufacture of most of the additives is in the nature of small batches, designed not only for a resin but for a specific manufacturer's resin, and it may be even more finely tuned than that.

One additives maker says that the normal pattern is that the firm will supply a heat stabilizer to a formulator with no trouble at all until one day the formulator calls and says that the stabilizer is not working. "Usually we find that the formulator has switched resins," he says, "and we have to tailor a new heat stabilizer for the new resin.

As a result, we seem to be coming up with a new stabilizer every two days."

Because of the exact nature of the additives, not only do the manufacturers need technical support personnel, but so do the resin producers, since many times they recommend the additive mix to the formulators, and so do the formulators of the resins. Thus, the cost of technical service in the additives industry is quite high from start to finish.

Among the largest-volume plastic additives are the plasticizers, flame retardants, heat stabilizers, antioxidants, and chemical blowing agents.

Plasticizer demand in 1980, according to Kline, was about 1.5 billion lb, down 9.7% from 1979. Producers expect demand to recover to 1979 levels sometime in 1982 and grow about 4 to 5% per year on average.

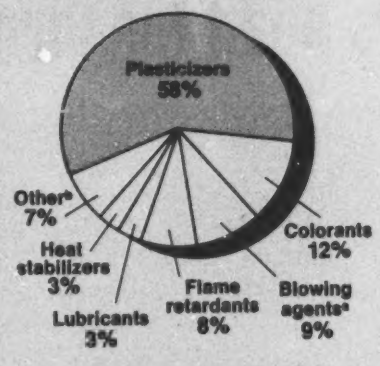
The main problem in plasticizer markets is that they are so closely tied to PVC—and flexible PVC at that. More than 80% of plasticizer demand is for flexible PVC, which is growing much slower than rigid PVC, which is still finding new markets. According to one producer, at one time flexible PVC accounted for about 60% and rigid about 40% of all PVC production. This ratio is changing rapidly and now flexible PVC is only about 45% of PVC production. It is expected that flexible will be down to 40% in just a few years.

Also in plasticizers, there is a trend to develop lower-density materials so that the customer gets greater volume for the same poundage. This may have a dampening effect on physical growth in the next few years, although the growth in value of the product may not be affected if the price increases as newer materials are used.

Flame retardants, one of only two additives whose volume didn't decrease in 1980, seem to have relatively slow but steady growth. Kline says that average annual growth has been just 2.2% per year for the past five years. Before that, government and other standards had almost ensured that growth in fire retardants was high—about 10% per year. One of the problems now is that major uses are in two of the lower-growth plastics—PVC and urethane. The growth rate for flame retardants may pick up once again, producers hope, as resins increase their penetration into construction and automotive markets.

Heat stabilizers were an 83 million lb market in 1980, according to Kline. Producers expect a 6 to 6.5% per year growth rate for the next few years. Like many of the other additives, the

Biggest-volume plastics additive is plasticizers



1980 Total = 2.6 billion lb

a Includes both physical and chemical blowing agents. b Includes organic peroxides, antioxidants, antistats, ultraviolet radiation absorbers, catalysts, curing agents, impact modifiers, and others.
Source: Charles H. Kline & Co.

biggest use for heat stabilizers is in PVC, largely with barium-cadmium stabilizers going for flexible, and organotin stabilizers for rigid. Thus, because rigid PVC is growing faster than flexible, producers see organotin stabilizers growing faster than barium-cadmium, though at present, demand for tin stabilizers still trails that for barium-cadmium. A third type of heat stabilizer, lead, is used mainly in PVC wire and cable applications.

As with the other additives, heat stabilizer producers are finding less of their product being used per pound of resin. However, the reasons vary for the different types of stabilizers. For instance, barium-cadmium additives are being cut because of toxicity problems with cadmium. Formulators want to use less of the organotins because of cost. And lead stabilizers, like barium-cadmium, have safety problems. Safety problems are also behind producers' efforts to develop different ways of shipping them to prevent "dusting." Prills and pellets are the most common.

Although not counted as a heat stabilizer, antioxidants enter the picture because, in some cases, they cut down on the use of heat stabilizers. The degradation process in PVC is somewhat an oxidation process under heat, according to producers. Thus, antioxidants cut the need for heat stabilizers in PVC.

According to Kline, antioxidant demand was about 32 million lb in 1980 with a value of about $37 million. About 30% of this market goes to polypropylene.

Producers say that antioxidant demand probably will increase about 4 to 4.5% per year for the next few years, with constant-dollar value increasing about the same amount. In general, forecasts for market growth of antioxidants parallel those for plastics, especially polyolefins.

And as with other additives, formulators would like to use less antioxidant in resin, but there is a special problem. Antioxidants already are used in such low concentrations (as low as 0.1 lb per 100 lb of resin) that it is difficult to control the concentration.

Chemical blowing agents are a fairly small-volume additive with the biggest use, again, in PVC. Demand for chemical blowing agents in 1980, according to Kline, was 14.9 million lb. Basically, there are just two U.S. producers of chemical blowing agents—Uniroyal and Stepan. However, this is the one area of the plastics additives business with foreign competition; at least four foreign firms are exporting to the U.S.

In one sense chemical blowing agents have it rather nice. The biggest end-use market for them is in packaging, which producers say is a fairly stable market. However, that is where nice ends. Under this steady packaging market come automotive, construction, and recreational uses, all of which are highly cyclical. In fact, if all of these industries should get together and have one good year at the same time, producers of chemical blowing agents would be ecstatic.

Industry forecasts for the chemical blowing agents market is for 6 to 7% per year growth for the next few years, with constant-dollar market value expanding slightly faster than that.

The absence of imports in almost all areas of plastics additives is unusual; with most specialty chemicals, imports play a big factor. One producer says that foreign companies just cannot supply the constant technical service needed in the U.S. In their own home areas, where they can supply this service, foreign firms are strong. Thus, the aspect is a two-edged sword. U.S. producers can't export to foreign countries to any great extent because of the cost of service, and foreign firms can't export to the U.S. for the same reason.

Thus, whatever markets develop for U.S. producers will have to be developed here. The shift of plastics producers to more durable resins may help in the long run, and growth of plastics additives, both in demand and in constant-dollar value, will closely follow plastics demand. □

Japanese chemicals struggle to recover

Japan's Economic Planning Agency says that the economic stagflation that has gripped the country finally seems to be bottoming out. Beleaguered Japanese chemical companies fervently hope that the agency is right.

Japan's chemical industry, particularly the petrochemical industry, hit rock bottom itself at just about this time last year. It has been struggling to recover ever since. Although most segments of the chemical industry now are doing better than they were a year ago, their recovery is far from complete. And indications are that complete recovery will be a long and painfully slow process.

After an encouraging start, the industry's problems started surfacing in mid-1980 when customers for basic petrochemicals and the major intermediates all but shut their doors in producers' faces. In anticipation of huge price increases, these customers had been buying large volumes of chemicals to build up their own inventories. This accounted for the surge in chemical production during the first half of the year. However, as Japan's economy slowed down, customers' demand for chemicals slowed down with it. They started working off their huge inventories.

The result was all too apparent on the bottom line of most chemical companies' earnings statements. Among the industry leaders, Sumitomo Chemical and Mitsubishi Chemical Industries suffered slight drops in profits, despite rising sales. But profits at Mitsubishi Petrochemical were down 40% and Mitsui Toatsu went about $66 million into the red.

All seven of the major synthetic fibers producers reported a drop in profits, ranging from about 15% to a hefty 88% for Unitika. Like many other Japanese petrochemical companies, the fiber producers blame rising costs of raw materials and energy along with their heavy burden of interest payments for a large part of their problems.

Unless Japan's economy improves much more rapidly than experts believe it will, Japan's chemical companies are in for another year of poor profits. Some already are resigned to another profits drop.

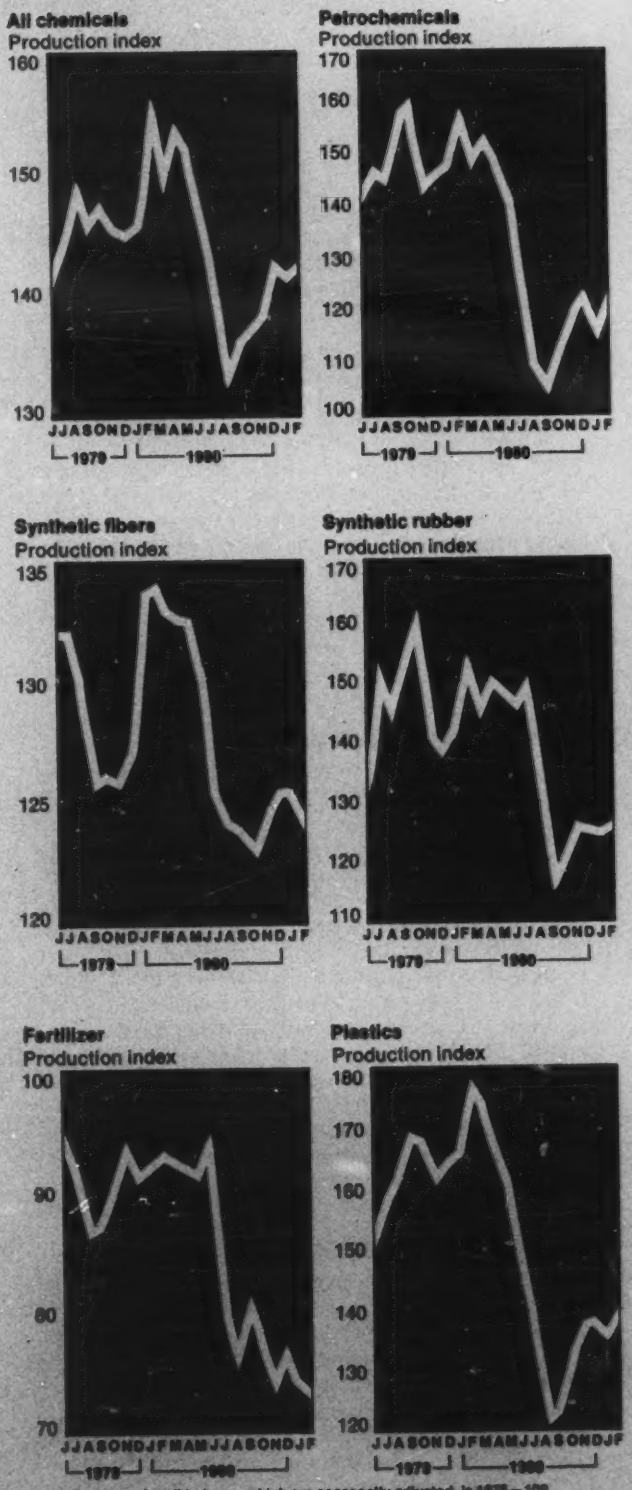
Even if the economy does improve, Japan's chemical industry can hardly look forward to spectacular results. It still is saddled with the same problem that has plagued it since the first energy crisis in 1973—high raw material costs.

Inexpensive imports, especially from the U.S. and Canada, continue to be a problem, too. So much so that the Ministry of International Trade & Industry (MITI) is looking at the possibility of applying antidumping and countervailing duties on chemical imports.

Realistically or not, some Japanese chemical companies think that imports will become less of a problem as the effect of oil price decontrol takes hold in the U.S. and when natural gas prices are deregulated. Some hope to regain ground lost to the U.S. in southeast Asia. But that won't be easy. Taiwan and South Korea also have their eyes on that market.

But for the rest of the year, at least, the industry's prime concern will be to keep profits from becoming worse than they already are.

Earl Anderson, New York



Note: Base year for all indexes, which are seasonally adjusted, is 1975 = 100.
Source: Ministry of International Trade & Industry

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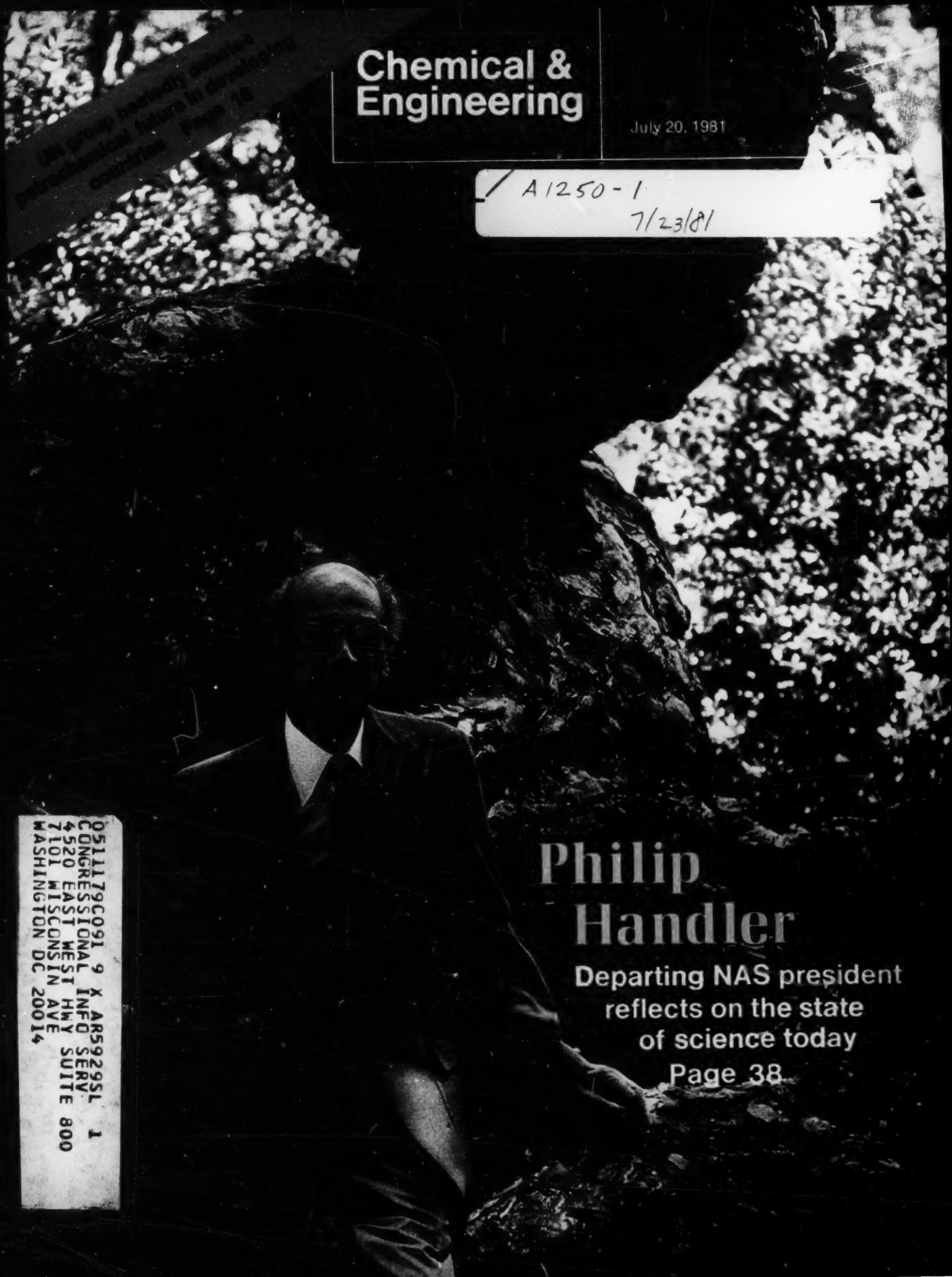

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Departing NAS president reflects on the state of science today

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Specialty monomers a labyrinthine business

Readers of the multitude of new product and new application announcements from companies are vaguely aware that there is a far-flung, almost hidden business in strange-sounding polymers made from monomers that in many cases are complex themselves. Far from the world of commodity polyethylene and polystyrene, these specialty products are obviously prolific and apparently expensive.

An enterprising consulting project has taken a stab at sizing up the entire field of specialty monomers. Emerging from talks with about 500 organizations in all parts of this business, Jerry Miron and Irving Skeist of Skeist Laboratories, Livingston, N.J., offer some totals:

- There are 170 specialty monomers, which Skeist defines as materials selling less than 100 million lb per year.
- These make up a U.S. business totaling nearly 1.5 billion lb per year worth more than $1.5 billion in 1980. In other words, the average price is $1.05 per lb. For background, commodity U.S. plastics sell currently at about 40 to 50 cents a lb and had a market of about 32 billion lb in 1980, according to the Society of the Plastics Industry. These prices are about 10 to 20 cents more than for the associated monomers.

Specialty monomers fall into two categories

	Number of materials	Average price 1980 ($ per lb)	Typical uses
OLEFINIC MONOMERS			**Via addition polymerization**
Unsaturated hydrocarbons	6	$0.45	Hydrocarbon resins, polyesters, EPDM
Allyls	11	1.90	Lenses, cross-linkers
Acrylic acid & esters	15	0.85	Polyelectrolytes, fibers, adhesives, coatings, radiation curing, cross-linking
Methacrylic acid & esters	19	0.90	Coatings, lube oil additives, ionomers, cross-linking, reinforced plastics, adhesives
Other unsaturated acids & derivatives	5	0.55	Paper size, polyesters
Acrylamide & derivatives	10	0.70	Polyelectrolytes for water, paper treatment
Quaternary compounds	6	1.10	Polyelectrolytes for water, paper treatment
Fluorine-containing compounds	9	4.00	Molding resins, solid lubricants, films, coatings, elastomers
Other vinyls	15	2.20	
TOTAL	96	$0.90	
OTHER MONOMERS			**Via polymerization by condensation, ring opening, and other routes**
Saturated & aromatic acids and derivatives	19	$1.65	Fibers, plastics, plasticizers
Glyoxal	1	1.20	Textiles & paper treatment
Alcohols	11	0.70	Polyurethane, polyesters, alkyds, foundry resins
Phenols	7	1.15	Polyphenylene oxide resin, epoxies, adhesives
Oxiranes, oxides	12	1.80	Epoxies
Aziridines	2	6.00	Cross-linker
Ethylenediamine & homologs	3	1.20	Epoxies, polyamines, polyamides
Cyclic amines	6	1.80	Polyimides, epoxies, fibers, elastomers
Isocyanates	4	2.90	Polyurethanes
Sulfone	1	1.50	Polysulfone
Silanes & other coupling agents (some unsaturated)	6	8.00	Reinforced plastics
TOTAL	74	$1.25	
GRAND TOTAL	170	$1.05	

Source: Skeist Laboratories

- There are about 70 specialty monomer producers and suppliers. Together, six of these make up a little less than half the market; the rest is highly fragmented.
- About half of specialty monomer production is used captively by the producer, and the other half goes to the merchant market.
- Growth can be high. Skeist says that one fourth of the poundage and one third of the dollar value is in specialty monomers growing 9 to 16% per year.

Skeist lumps the specialty monomers into two main groups. One is olefinics, which polymerize through their carbon-carbon double bonds in addition reactions. The other is everything else, monomers that form polymers by other mechanisms such as condensation or opening a heterocyclic ring.

These two groups are about equal in dollar volume, the study finds. However, the olefinics are more numerous and cheaper. Skeist counts 96 of them with an average price of 90 cents a lb. In the "other" category, the 74 monomers sell at an average $1.25 per lb.

Besides the high growth characteristic, Skeist finds other attractive aspects for many of these compounds. These include patent protection, integration with polymer production and sometimes with end uses, and high value-added.

A common force for growth in many leading markets for specialty monomers is sociopolitical pressure for energy conservation, new energy sources, pollution control, and safety. These problems have induced faster development of polymer engineering to impart new or improved specifications to end products such as autos and houses. The push for higher-performance polymers has led to a push for precursor chemicals with a variety of functional groups.

For example, the drive for improved water quality has boosted the market for polymeric flocculants used to remove suspended solids in potable water treatment and industrial water processing. Air quality campaigns underlie trends toward water-based latexes and high solids content in organic solvent-based coatings. The move to increase end products' fire

retardance has favored use of three kinds of monomers yielding polymers that are slow-igniting, slow-burning, or self-extinguishing. The key functional groups are phosphorus, halogens, and aromatic rings.

A specific example of the fire-retardant compounds is General Electric's polyphenylene oxide, which Skeist calls a polyblend or alloy of poly(2,6-xylenol) with high-impact polystyrene. The aromatic content is high, conferring the flame retardance required for television components, lighting equipment, business machines, appliances, auto parts, and other uses.

Besides these monomers linked directly to quality-of-life market growth, many others are advancing mainly because of a unique ability to do a job. Skeist goes through a long list, including compounds such as ethylidene norbornene and 1,4-hexadiene used as cross-linkers in rubber, cyanoacrylates in instant adhesives, aminoundecanoic acid in nylon 11, methylene dianiline in polymeric isocyanates and other polymers, resorcinol in tire cord adhesive, and silanes in coupling agents.

In a section on new developments, the study looks at monomers and polymers with promising futures. For example, the study concludes that heat-resistant polymers, targeted for aircraft and aerospace uses in continuous service at 600 °F, will find extensive application. Although there is a theoretical limit to the heat resistance of organic matrices, there is still much room for improvement. Rings with conjugated unsaturation are being generated in these polymers by the trimerization of acetylene or nitrile end groups in monomers.

Another example is medicinally oriented polymers. One development is polymeric drugs containing a large fraction of carboxyl groups, active as interferon inducers resulting in antiviral and possibly anticancer activity. Even more interest is going to drug molecules that can be attached to a polymeric backbone.

In advising clients on possible entry into specialty monomers, Skeist suggests acquiring a spinoff unit of a larger organization. The study points out that most monomer suppliers offer only one or two items. In some cases, a multinational company may be quite happy to relinquish a material which no longer fits its own objectives but may fill a niche in another company's product structure. Skeist adds that several chemicals formerly made by U.S. firms must now be imported from Europe or Japan. □

Butadiene still needs dehydrogenation units

"On purpose" butadiene (butadiene made by independent plants through dehydrogenation of *n*-butane or butylenes) will continue to be needed, especially in the western hemisphere. Therefore, U.S. dehydrogenation capacity for butadiene of just over 1 billion lb a year will be run for some time yet. Don't count it out.

The reason is changes in feedstocks and operation of steam crackers used to make olefins, particularly ethylene, concludes a world butadiene survey just issued by Ericsson Consulting Services, a department of DeWitt & Co. of Houston. These changes reduce the amount of butadiene produced as coproduct with ethylene and consequently reduce the worldwide supply of butadiene.

One of the changes is the continued, if not growing, emphasis on light hydrocarbon feedstocks for steam crackers in the U.S. and elsewhere. Another change is lower plant operating rates in Europe and Japan for naphtha-fed steam crackers as new ethane-fed crackers come on stream in the Mideast, Far East, Canada, and Mexico.

According to the survey, worldwide consumption of butadiene will exceed 5.1 million metric tons in 1981, up about 2% from 1980. In 1980, western hemisphere consumption almost topped 2 million metric tons, or just under 40% of worldwide use.

In 1981, the Ericsson survey estimates, U.S. consumption will be more than 3.6 billion lb, about 500 million lb of which will be imported. Dehydrogenation is expected to provide 31% of U.S. production, with coproduct accounting for the rest.

U.S. consumption of butadiene in 1981 will increase almost 6% over 1980 but still will be less than in 1979 after a 13.5% decline in 1980.

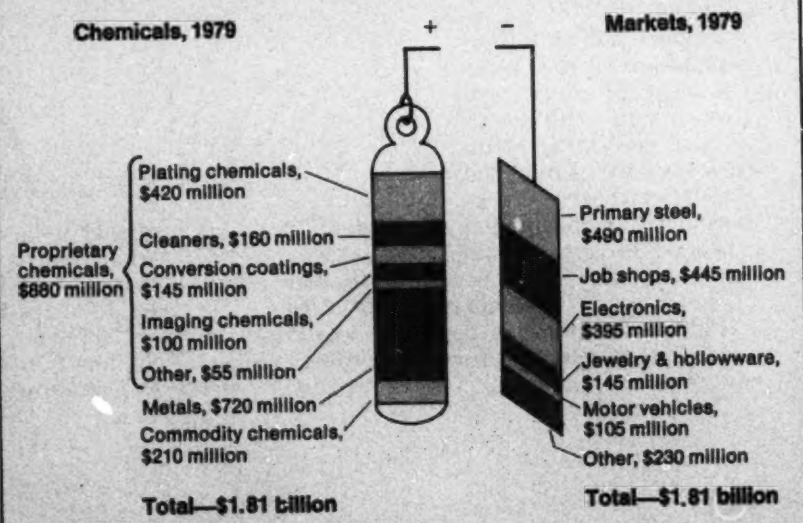
Unless unusual economic conditions develop, U.S. consumption of butadiene will increase 200 million lb in both 1982 and 1983. Hence U.S. consumption could exceed 4 billion lb in 1983. □

Metal-finishing chemicals use sagged in 1980

Though U.S. sales of metal-finishing chemicals dipped with the rest of the economy to $1.7 billion in 1980 (from $1.8 billion in 1979), a study by Charles H. Kline & Co., Fairfield, N.J., chemical industry consultant, finds this mature but profitable market swelling to $2.2 billion in 1985 in constant 1979 dollars. Kline views printed circuit boards as part of this market, in addition to plating, galvanizing, and conversion coatings. Conversion coatings include such anticorrosion treatments as phosphatizing and chromatizing preparatory to other coating or plating.

Indeed, had Kline not included electronics plating, which alone made

Sales of metal-finishing chemicals break down this way



Source: Charles H. Kline & Co.

Reactivity of Metal-Metal Bonds

ACS Symposium Series No. 155

Malcolm Chisholm, *Editor*
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modest increases in 1980, the dip in metal-finishing chemicals markets would have appeared sharper. And the electronics industry will spearhead the advance to bigger sales in 1985, with a 7.8% annual increase to $1.03 billion from $300 million in 1979 for photofabricating chemicals.

Because of poor economic conditions in 1980, Kline studied the metal-finishing chemicals market for both 1979 and 1980 and based growth rates on the more representative 1979 figures.

For example, the $420 million sales of plating chemicals in 1979 took a dip to $390 million in 1980. Cleaners fell to $140 million from $160 million in 1979. Conversion coatings dropped in the same period to $140 million from $145 million, whereas imaging chemicals, the type used in electronics device processing, rose to $110 million from $100 million. Elsewhere outside the electronics industry, metals for anodes or galvanizing zinc plummeted to $665 million from $720 million the previous year. Commodity chemicals used in the industry dropped to $205 million in 1980 from $210 million in 1979.

Kline classes the metals used in plating and galvanizing into three categories. If sold as part of a proprietary plating bath, they are plating chemicals. Metals sold as anodes or zinc for galvanizing are termed metals. If finishers buy their own metal salts to make up their own baths, they are called commodity chemicals.

Among the processes used in metal finishing, plating on metal is the most important, with $930 million in 1979 chemical sales taking more than half the market. This outlet fell to $865 million in 1980, although overall, plating on metal will contribute $100 million (from the 1979 level) to the growth toward the 1985 market of $2.2 billion.

Galvanizing as a process accounted for $275 million in chemical sales in 1979 and $235 million in 1980. Conversion coatings declined to $200 million from $205 million. Reflecting the overall health of the electronics industry, photofabrication processing rose to $310 million in 1980, compared to $300 million in 1979.

Government regulations continue to hit the metal-finishing industry hard, though problems for finishers could become opportunities for suppliers. For example, alleviation of chromium plating wastes and substitutes for cadmium and cyanides are among the opportunities for which research may enable suppliers to fill a niche. □

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Ethyl mercaptan
n-Propyl mercaptan
iso-Propyl mercaptan
n-Butyl mercaptan
sec-Butyl mercaptan
iso-Butyl mercaptan
tert-Butyl mercaptan
n-Hexyl mercaptan
Cyclohexyl mercaptan
n-Octyl mercaptan
tert-Octyl mercaptan
tert-Nonyl mercaptan
n-Dodecyl mercaptan
tert-Dodecyl mercaptan
tert-Tetradecyl mercaptan
tert-Hexadecyl mercaptan
tert-Mixed mercaptans
(C_9, C_{12})
(C_{12}, C_{14}, C_{16})
2-Mercaptoethanol
Benzyl mercaptan

Sulfides
Ethylthioethanol
Di-n-butyl sulfide
Di-tert-butyl sulfide
Ethylthioacetate
Phenylthioethanol

Disulfides
Di-tert-butyl disulfide
Di-tert-dodecyl disulfide
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Developing nations' petrochemical role debated

Delegates from 49 countries at UNIDO meeting discuss licensing agreements and prospects for petrochemical industry in developing nations

Dermot A. O'Sullivan
C&EN, London

The underlying brittleness that exists between the "haves" and the "have nots" in the world of petrochemicals surfaced in Istanbul last month. The occasion was the second consultation on the petrochemical industry organized by the United Nations Industrial Development Organization (UNIDO), and hosted by the Turkish government.

Discussions, which at times bordered on the acrimonious, centered on two topics. One was a model form of licensing agreement drawn up by the UNIDO Secretariat, headquartered in Vienna. The other was long-term arrangements for the development of the petrochemical industry in developing countries, including arrangements for marketing petrochemicals produced in those countries.

No firm decisions were reached at the week-long meeting, although, in fairness, none were anticipated. Delegates spent their time—at one point extending into the early hours and cut short only by Turkey's 2 AM curfew—debating and nitpicking the wording of the working documents UNIDO provided.

However, UNIDO was called on to examine in greater depth long-term arrangements for developing the petrochemical industry in developing countries and ways and means of mobilizing the required financial resources. It was asked to identify opportunities for cooperation between industrialized and oil- and gas-producing developing countries toward establishing downstream petrochemical operations in other developing countries, and to evaluate schemes for manpower training in the industry. A third consultation likely will take place in two or three years.

Typical of the dissensions that surfaced was the view by potential licensees from developing countries that they expected better terms and conditions than licensors from industrialized countries were prepared to provide under current international practice. There were divergent views on such matters as the liability of a licensor to remedy defects in the licensed process, the scope of performance guarantees, penalties, secrecy provisions, and the range of services to be provided.

Forty-nine countries spanning the alphabet from Algeria to Yugoslavia were represented. Also at the meeting were members of such UN bodies as the United Nations Center on Transnational Corporations, the United Nations Conference on Trade & Development, and the World Bank. In addition, there were representatives from the Arab Industrial Development Organization, the European Council of Chemical Manufacturers' Federations (CEFIC), the European Economic Community, the Gulf Organization for Industrial Consulting, the Organization of Arab Petroleum Exporting Countries, and the World Federation of Trade Unions.

The Istanbul meeting was a direct outgrowth of the first UNIDO consultation on petrochemicals held in Mexico City in 1979. That, in turn, was prompted by the Lima (Peru) declaration of 1975 that the developing world should have at least a 25% share of the total global industrial output by 2000. The share carried by the petrochemicals sector, it is felt, should be higher to help lift the overall average to the targeted 25% minimum.

There's a certain aura of glamour still associated with petrochemicals, despite the currently depressed state of the market for many of the products. This glamour is attracting growing attention from an increasing number of developing countries. Many view a petrochemical project as something of a status symbol, comparable in a degree to having a national airline.

Of course, some of these countries are in the enviable position of having ample supplies of oil and gas. So it's only reasonable that they should want to convert this valuable resource into downstream products that yield better financial returns, while providing more local employment opportunities and raising living standards in the process. Such countries seek some form of association with the developed world. These ambitions are the basis of the so-called "north-south" dialogue.

Less fortunate developing countries without indigenous hydrocarbon resources would like to form links with those that have, and establish a source of supply of some of the basic petrochemicals and polymers for local conversion to usable products. Negotiations toward this end are central to what has come to be termed the "south-south" dialogue.

"So far, the developing countries have planned to establish only 10 export-oriented petrochemical complexes," says Abd-El Rahman Khane, UNIDO's executive director. "Even if all their production were exported to developed countries, it would account for only about 5% of the requirements of developed countries in 1990 for ethylene derivatives, and 12% for methanol," he reasons. "However, a larger part of this production is likely to be exported to other developing countries, which in 1979 imported about 40% of their requirements for plastics, synthetic fiber intermediates, and synthetic rubbers."

Established petrochemical producers in Western Europe, Japan, and the U.S., meanwhile, are viewing the turn of events with a hint of alarm. For them, the groundswell of expanding ambitions on the part of the developing countries is coming at a particularly inappropriate time. Many of their existing production facilities are running well below the economic break-even point—some, indeed, lie idle—prices are weak; profits, where they exist, are slim; and overall unemployment levels are inordinately high.

Martin Trowbridge, director general of the U.K. Chemical Industries Association, didn't mince words when he addressed one of his group's conferences in London as far back as 1977. "The stated intentions of some OPEC countries to use their oil profits to build large-scale petrochemical

plants could pose a serious threat to jobs in the U.K. and European chemical, plastics, and textile fiber industries," he said. "Their intentions are not in doubt. The only uncertainty is on the scale, timing, and effectiveness of executing their plans."

Trowbridge draws a distinction between those OPEC countries with populations large enough to absorb the products, and those "with big oil revenues, low populations, and the need to unload their products elsewhere. In the latter countries," he says, "the profits from chemicals would be added to profits from oil and invested again to produce even more chemicals.

"Such gross overproduction in countries with small populations, but bountiful and marginal-cost oil feedstocks, could depress prices and severely damage our European industry," he warns. "The direct and indirect effects on the economy could throw many people out of work. I take the view that a significant part of the impact will be felt in European and world markets within 10 years."

There seems little doubt, however, that the production profile of commodity petrochemicals will undergo a shift toward the oil- and gas-rich developing countries. Dow Chemical Europe president Frank P. Popoff, for one, sees the shift taking place fairly rapidly between now and the turn of the century (C&EN, June 1, page 6).

James H. Butler, vice president of the business development group for Mobil Chemical Co.'s petrochemicals division in New York City, shares Popoff's view. Speaking in Lausanne, Switzerland, last month at a conference titled "Strategies for the Eighties" sponsored jointly by *Modern Plastics* and Platt's *Polymerscan*, he said, "The high cost of basic petrochemicals is overshadowed by the coming change in the geographic sources of these products. [There] is the emerging trend of hydrocarbon-rich countries to build major petrochemical and resin operations almost entirely for export sales. Large-scale joint ventures in Saudi Arabia by Mobil, Exxon, Shell, Dow, and Mitsubishi will export virtually all of their production. Similar plans [are under way] in Mexico, Indonesia, Qatar, and elsewhere.

"The building of large plants solely for export will create a truly global marketplace with intensified competition. It also will diminish the prospects for the industrialized nations to maintain their shares of international resin markets. In fact, the industrial nations will do well if they can prevent erosion of their respective domestic markets as higher import levels from these exporting operations become a significant factor.

"All of these exporting operations will tend to focus around a relatively narrow range of products. Since most of the hydrocarbon-rich countries will be seeking to utilize natural gas and gas liquids, most of the petrochemical products will be derived from ethylene and propylene. Obviously, we are going to see large quantities of commodity resins—polyolefins, polyvinyl chloride, or its ethylene dichloride precursor—and, when there are related nearby refinery operations, aromatics, styrene, and perhaps polystyrene."

Commented one of the European delegates at Istanbul, "Obviously petrochemical investments will become a more significant factor in the developing world. We don't dispute that. But we would dispute the speed and scale of the investments. It would seem that the developing countries' ambitions are outreaching the facts of life."

He and his associates from the industrialized countries take exception to some projections and conclusions contained in a massive, 482-page study compiled by the UNIDO Secretariat on the worldwide petrochemical industry that served as a background to the Istanbul discussions. They argue, for example, that values of anticipated future output by developing countries are unrealistically high within the short-term time frame of the report.

The case for installed ethylene production capacity is an example. According to UNIDO, some 30 developing countries shared a total output capability of 7.3 billion lb in 1979. This level is expected to more than double to 17.4 billion lb in 1984, and all but double again to 32.8 billion lb by 1987. Put another way, the average annual growth in capacity over the eight-year span would be almost 21%. There is no way, critics maintain, that such a high level of capacity growth will be achieved.

According to the UNIDO study, demand for the five principal thermoplastics—low- and high-density polyethylene, polypropylene, polyvinyl chloride, and polystyrene—among the developing countries will move up from 14.8 billion lb in 1979 to 48.4 billion lb by 1990, an average annual increase of 11.4%. Next in terms of growth will be styrene-butadiene and polybutadiene rubbers, demand for which will expand 8.3% annually from a combined 1.8 billion lb in 1979 to 4.4 billion lb in 1990.

UNIDO predicts developing countries' share of petrochemical output will increase greatly by 1990

	Total world output		Developing countries			
			Output		Share of total %	
Millions of lb	1979	1990	1979	1990	1979	1990
COMMODITY PETROCHEMICALS	213.84	408.98	16.20	69.56	7.6%	17.0%
Ethylene	82.72	154.88	6.01	30.80	7.3	19.9
Propylene	43.34	81.18	2.62	9.83	6.0	12.1
Butadiene	11.00	18.26	0.88	3.52	8.0	19.3
Benzene	37.84	67.76	2.60	11.00	6.9	16.2
Xylenes	13.42	26.18	1.45	6.60	10.8	25.2
Methanol	25.52	60.72	2.64	7.81	10.3	12.9
THERMOPLASTICS	90.42	176.66	8.14	48.18	9.0	27.3
Low-density polyethylene	26.84	48.40	2.42	15.18	9.0	31.4
High-density polyethylene	12.76	24.64	0.66	5.94	5.2	24.1
Polypropylene	11.00	27.72	0.66	6.60	6.0	23.8
Polyvinyl chloride	26.84	51.92	3.52	15.84	13.1	30.5
Polystyrene	12.98	23.98	0.88	4.62	6.8	19.3
SYNTHETIC FIBERS	22.00	33.00	3.96	11.22	18.0	34.0
Acrylic	4.18	5.94	0.66	1.78	15.8	30.0
Polyamide	7.04	9.68	0.97	2.53	13.8	26.1
Polyester	10.78	17.38	2.33	6.91	21.6	39.8
SYNTHETIC RUBBERS	14.08	22.00	1.10	4.36	7.8	19.8
Styrene-butadiene	11.44	17.60	0.88	3.59	7.7	20.4
Polybutadiene	2.64	4.40	0.22	0.77	8.3	17.5

Source: United Nations Industrial Development Organization

UNIDO sees fast capacity buildup for petrochemicals like ethylene

Millions of lb	1979	1984	1987
AFRICA			
Algeria	264	264	264
Egypt	0	0	308
Libya	0	726	726
Nigeria	0	0	616
ASIA			
China[a]	1118	2,090	3,982
India	528	528	2,024
Indonesia	0	0	770
Iran	66	66	660
Pakistan	0	0	220
Philippines	0	0	550
South Korea	330	1,879	2,640
Singapore	0	660	660
Thailand	0	0	330
Others	1254	2,024	2,024
LATIN AMERICA			
Argentina	374	550	1,210
Bolivia	0	0	352
Brazil	1628	2,684	2,684
Chile	132	396	396
Colombia	44	264	264
Ecuador	0	0	220
Mexico	968	3,168	4,268
Peru	0	0	550
Venezuela	330	330	1,100
MIDDLE EAST			
Iraq	66	352	352
Kuwait	0	0	660
Qatar	0	616	616
Saudi Arabia	0	0	3,520
Turkey	132	792	792
TOTAL	**7304**	**17,380**	**32,758**

a People's Republic of China. Source: United Nations Industrial Development Organization

Synthetic fibers' use will increase at the relatively slower rate of 6.8% per year from 5.4 billion lb in 1979 to 11.2 billion lb in 1990.

By 1990, according to UNIDO's projections, the developed countries' output for these petrochemical derivatives will match demand, a conclusion that observers from the developed countries treat with some skepticism.

Criticism also came from delegates of the developing countries. But as Surjit S. Sachdeva of India's Ministry of Petroleum, Chemicals & Fertilizers, who chaired one of the sessions, notes, "We are dealing with a subject that is not simple. One can always find fault with numbers. We should, rather, concentrate on the conclusions of the advantages arising from the petrochemical industry in countries where oil and gas are available."

Were all the projects UNIDO lists to go ahead, the costs would be staggering. Heavy borrowing would be called for. And as it is, there is concern in many quarters now at the extent of debts that have been incurred by the developing world, particularly those countries that are dependent on imported oil.

According to Jacques de Larosière, managing director of the International Monetary Fund, these latter countries' combined deficit this year will approach $100 billion compared to last year's $82 billion total. Speaking before the UN Economic & Social Council in Geneva earlier this month, he said, "Imbalances of this magnitude couldn't be sustained. The debt resulting from their financing is becoming increasingly burdensome, and in some cases intolerable."

The woeful lack of an industrial infrastructure in many developing countries, which will make installation of sophisticated plants that much more difficult, is another reason for the element of skepticism on the part of those from the industrialized world. And it is true that even in the U.K., for example, where roads, docks, engineering skills, and the like are all at hand, completion of some petrochemical complexes has overshot the planned completion dates by several years, thereby adding to costs.

On the other hand, companies that are committed to major projects in Saudi Arabia, which, despite its considerable wealth, still is classed as a developing country, are confident that their plants will be ready to run in 1985 or 1986. Mobil, for instance, will make ethylene, ethylene glycol, LDPE, and HDPE at Yanbu adjacent to a 250,000 barrel-per-day refinery it is building there (C&EN, Dec. 22, 1980, page 52). "These projects are real," insists Mobil's Butler. "We are committed to bringing [them] on stream and on schedule. Our [petrochemicals] joint venture [with] Saudi Basic Industries Corp. is expected to satisfy Mobil's normal investment and profitability criteria. We have no reason to believe that the other joint ventures in Saudi Arabia will be operated any differently."

Some developing countries, typically Qatar and Saudi Arabia, have taken the joint venture approach to building up their petrochemical capabilities, choosing as partners companies headquartered in Western Europe, Japan, or the U.S. In this way they have access to the partner's technology, provision of worker training programs, and so forth, as well as to its global market outlets for the products.

It was made obvious at Istanbul, however, that many developing countries are against joint ventures as such. They prefer to plan and operate their projects independently, unhampered by ties to an outside partner. And considerable time was spent, without too much success, debating replacement of the term "joint venture" in the documents with alternate wording.

These countries favor some form of "association" or "cooperation." Some would even consider a regional collaboration. At the same time, they would still seek technical know-how through licensing, and expect assistance in personnel training and in channeling products onto world markets. But as one observer from a large international concern privately noted, technology is a key trump card held by chemical-producing companies in the industrial world. Outright sale of know-how, without gaining an equity position in a particular venture, wouldn't make economic sense to most.

Many participants at the meeting took the view that before any useful discussion on long-term arrangements takes place, the restructuring process taking place in the industry should be examined to see if there is any need for such arrangements. It was generally agreed that restructuring already is proceeding under the influence of rising feedstock and energy costs in "traditional" production centers. Others noted that petrochemicals, particularly the basics and intermediates, can be made competitively in oil- and gas-producing developing countries.

On this, a developing country delegate strikes a note of caution: "What will happen if each country or region represented here goes ahead with its own petrochemical plants? Such action," he says, "would lead to capacity oversupply, and we will all be the losers."

Khane explains that "UNIDO has attempted to demonstrate the considerable potential for new producers based on the anticipated expansion of world demand for petrochemicals to 1990 and beyond, and the large number of plants that need to be replaced in developed countries in the next 10 years. Considering the production cost advantages of developing countries endowed with large oil and gas resources, their claim to play a more important role in the future of this industry seems to us fully justified." □

ACS study shows OSHA rules won't work in labs

The American Chemical Society has told the Occupational Safety & Health Administration that setting rigid standards for worker exposure to hazardous chemicals in laboratories is not an effective way to protect laboratory workers' health, and that safety training programs should be the keystone to OSHA's laboratory safety and health policy. A recent ACS survey supporting this view shows that the use of toxic chemicals in labs tends to be in very small quantities for limited amounts of time, and that they are used by professionals and informed workers.

OSHA is considering regulations to protect laboratory workers from exposure to hazardous chemicals and is seeking alternatives to the substance-specific standards that are used for protection of chemical plant employees. The agency currently has regulations requiring exposure monitoring for use of 27 chemicals, such as benzene, asbestos, arsenic, and lead. Unless OSHA establishes regulations or guidelines specifically for labs, these employees will be subject to the same rules as plant workers.

ACS conducted its extensive survey of lab practices concerning hazardous chemicals to give some solid information to OSHA. The survey was prepared by the ACS Task Force on Occupational Safety & Health, chaired by Inara M. Brubaker of UOP Inc., Des Plaines, Ill. Questionnaires were mailed to 1439 labs of all sizes and functions—academic, private, and industrial—chosen at random from the more than 5300 facilities in the U.S. Response to the survey was excellent, with slightly more than 40% of the forms returned. Analysis of the survey was by the ACS Department of Public Affairs and the results were sent to OSHA last week.

The ACS survey replies to five general statements concerned with use of hazardous chemicals in labs and how lab workers should be protected. The statements were first brought up when debating the OSHA cancer policy, and although generally believed to be true within the scientific community, there had not been much evidence to back them up. ACS contends that its survey supports the statements, which hold that rigid monitoring and engineering controls to reduce toxic chemical exposure are not effective in laboratories.

The first general statement contends that labs handle a large number of toxic chemicals and that routine monitoring of all of them isn't possible because monitoring methods don't exist or there are no applicable OSHA standards. ACS found that 51% of labs responding use more than 25 chemicals daily, and that 9% use more than 200 chemicals daily. That the best protection is believed to be better training is demonstrated by the finding that 36% of the labs have voluntarily improved working conditions for handling hazardous chemicals and 38% have improved employee safety programs.

A second belief is that routine monitoring for exposure to toxic chemicals will not work because of the short-term and low-level use of these substances by lab workers. The survey showed that about 76% of the labs use OSHA-regulated chemicals, and in most of these, only about 10% of the workers use those substances. More than 70% of the labs with OSHA-regulated chemicals said they had them in less than 50-g quantities (except benzene). Still, 20% of the labs reported having some kind of personal monitoring program where it seems warranted by the use and toxicity of the chemicals.

A third statement used to argue against rigid standards is that it cannot be predicted what chemicals will be used in a laboratory, hence it is not possible to monitor them effectively. The ACS survey finds this to be true. Of the labs responding, 45% said they make up to nine unexpected chemical purchases per year and 3.5% said they make more than 150 unexpected chemical purchases.

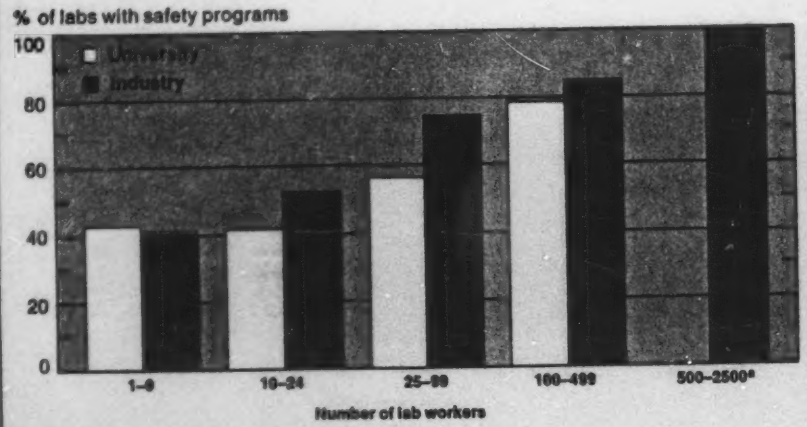
Another argument is that lab workers or their supervisors are highly trained concerning the use of chemicals and that decisions on worker safety would best be left in their hands. The ACS survey confirms that most workers are highly trained, finding that better than 73% of all lab workers have at least a bachelor's degree. Safety programs also are increasing worker awareness of hazards. The survey shows that only 7.8% of industrial lab workers are employed where there is no safety program, and that just 33.3% of academic workers are not involved in a safety program of any kind.

The final statement is that monitoring would be prohibitively expensive and that more good for the worker would be done by improving work practices and facilities. The survey finds that most monitoring programs cost less than $500 per person but 17% of those responding said it costs them more. And this does not just include monitoring of OSHA-regulated chemicals, but mercury, toluene, formaldehyde, and many others not listed by OSHA.

ACS recommends that OSHA establish good chemical practice guidelines for lab workers and that the guidelines require safety programs in all labs. The society suggests that OSHA use the National Academy of Sciences report "Prudent Practices for Handling Hazardous Chemicals in the Laboratory" as a guide for developing the safe work practices. In general, ACS maintains that all chemicals should be handled properly and carefully, not just those labeled hazardous.

David Hanson, Washington

Likelihood of a lab safety program increases with the number of lab workers



a No university labs reporting had more than 500 workers.

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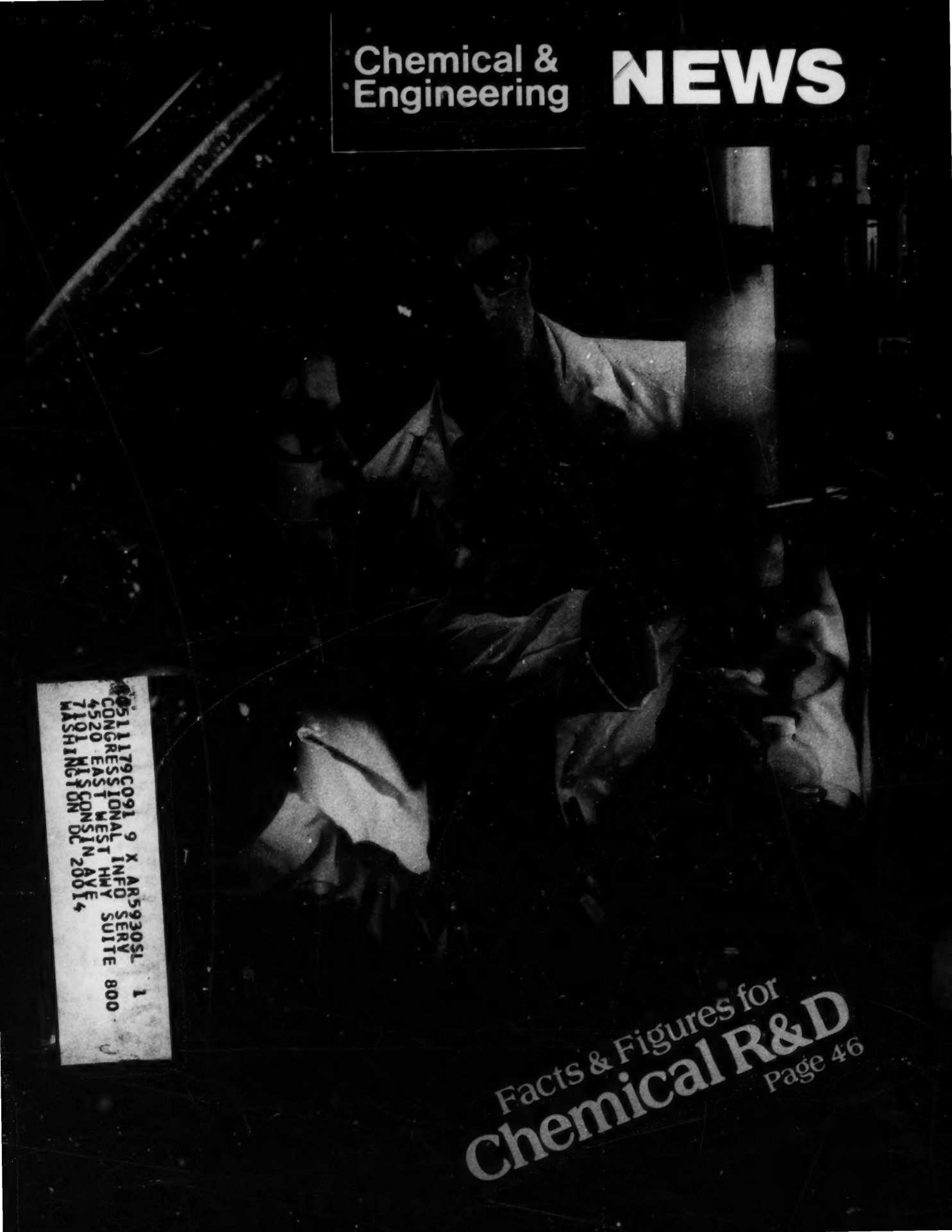

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CHEMICAL EARNINGS RISE IN SECOND QUARTER

Despite a slowing in price increases, only slow production growth, rising value of the dollar, and weak overseas business, earnings for U.S. chemical firms in the second quarter are higher than they were in second-quarter 1980. And in many cases, they are substantially higher.

Of 26 companies surveyed thus far by C&EN, only three—Ethyl, Texasgulf, and Philip A. Hunt—had decreased earnings for the quarter.

Leading the earnings gains is long-troubled Reichhold Chemicals, with an increase so large it is almost meaningless. In the second quarter Reichhold's earnings increased 2586% to $5.5 million from just $204,000 in the second quarter last year. Its sales increased 19% to more than $254 million. Reichhold's profit margin, however, increased to only 2.2% from 0.1% at this time in 1980.

For Du Pont, the largest U.S. chemical firm, earnings rose 51% to $262 million on a sales gain of 14% to $3.93 million.

Fiber-related companies continued to perform well in the second quarter, just as they had in the first quarter, indicating that some sort of turnaround in fibers may well be real.

Akzona's earnings rose 233% from a year before to $4.8 million. Sales reached $314 million, a 14% increase from last year's second quarter. Like Reichhold, however, the big increase at Akzona did not bring luster to its profit margin, which increased to only 1.5% from 0.6% in the second quarter of 1980.

Monsanto did better in terms of profitability, increasing its profit margin to a fairly respectable 5.0% from 1.5% last year on the strength of a 304% earnings increase in the second quarter. Net income for the quarter was $93.8 million compared to $23.2 million in the second period of 1980. Sales at Monsanto jumped 20% to $1.86 billion in this year's second quarter.

Celanese also was helped by fibers in the second quarter; its earnings rose 64% to $41 million, and sales increased 25% to $1.0 billion. In spite of Celanese's good performance, its second-quarter earnings were hurt by a loss in its non-U.S. fibers operations.

Foreign business seemed to be a problem for many chemical companies in the second quarter. In spite of good results, many of them continued to complain of poor overseas business. To this was added a new problem—the strengthening of the dollar against foreign currencies. The stronger dollar, they say, is making

Second-quarter earnings are up substantially at most chemical companies

	Second-quarter 1981						First-half 1981					
			Change from 1980		Profit margin[b]				Change from 1980		Profit margin[b]	
	Sales	Earnings[a]	Sales	Earnings	1981	1980	Sales	Earnings[a]	Sales	Earnings	1981	1980
Air Products	$387.6	$28.0	9%	4%	7.2%	7.6%	$800.6	$64.9	9%	6%	8.1%	8.3%
Akzona	314.0	4.8	14	233	1.5	0.6	622.9	7.5	16	11	1.2	1.3
Allied Corp.	1585.0	87.0	16	19	5.5	5.4	3167.0	171.0	15	21	5.4	5.1
American Cyanamid	900.0	42.2	8	29	4.7	3.9	1787.0	89.3	7	26	5.0	4.2
Celanese	1002.0	41.0	25	64	4.1	3.1	1650.0	61.0	16	26	4.0	3.7
Diamond Shamrock	786.3	55.8	6	5	7.1	7.2	1623.8	113.5	11	8	7.0	7.2
Dow Chemical	3066.9	181.0	22	6	5.9	6.8	5963.8	309.9	12	−23	5.2	7.5
Du Pont	3929.0	262.0	14	51	6.8	5.1	7606.0	466.0	8	12	6.2	6.0
Essex Chemical	52.1	3.5	39	150	6.7	3.7	92.0	4.4	30	110	4.8	3.0
Ethyl Corp.[c]	453.4	23.6	3	−2	5.2	5.5	878.6	44.1	nc	−16	5.0	6.0
Freeport-McMoRan	208.2	43.3	33	2	20.8	27.3	432.8	89.0	35	4	20.6	26.8
B. F. Goodrich[d]	828.5	20.6	10	106	2.5	1.3	1608.9	29.0	7	−4	1.8	2.0
W. R. Grace	1687.1	99.4	9	18	5.9	5.4	3173.8	182.5	8	21	5.8	5.1
Hercules	712.0	33.5	14	22	4.7	4.3	1380.0	69.0	9	14	5.0	4.8
Philip A. Hunt	26.6	1.2	3	−43	4.0	7.3	54.7	1.3	1	−62	2.4	6.4
Monsanto	1865.0	93.8	20	304	5.0	1.5	3756.0	269.8	11	44	7.2	5.6
Olin	544.6	32.9	12	21	6.0	5.6	1066.3	61.3	11	25	5.7	5.1
Pennwalt	308.7	12.7	8	17	4.1	3.8	603.7	15.3	4	−34	2.5	4.0
PPG Industries	892.9	64.0	19	61	7.2	5.3	1700.0	116.5	10	23	6.9	6.1
Reichhold Chemicals[e]	254.3	5.5	19	2586	2.2	0.1	493.1	9.5	10	116	1.9	1.0
Rohm & Haas[f]	545.4	33.4	17	24	6.1	5.8	1024.1	58.2	13	7	5.7	6.0
Stauffer Chemical	377.2	23.1	6	16	6.1	5.6	1006.5	111.0	7	24	11.0	9.5
Texasgulf[g]	278.3	57.6	16	−3	20.7	24.6	553.6	142.5	6	−29	22.3	33.7
Thiokol	177.6	8.8	21	16	5.0	5.2	189.3	17.0	25	1	9.0	11.3
Union Carbide[h]	2674.9	193.4	13	29	7.2	6.3	5314.5	371.4	6	nc	7.0	7.5

a After-tax operating income excluding extraordinary and nonrecurring items. b After-tax income as a percentage of sales. c Excludes charge of $6.8 million in second-quarter 1980 and gain of $7.3 million in first-quarter 1980. d Excludes nonrecurring gain of $18 million in first-half 1981. e Excludes $2.4 million charge in second-quarter 1981. f Excludes $13.4 million charge in second-quarter and $7.6 million nonrecurring gain in first-quarter 1981. g Excludes $16.6 million nonrecurring gain in first-half 1981. h Excludes $217.3 million nonrecurring gain in first-quarter 1980. nc = no change.

their products more expensive overseas, which is hurting exports.

For the three earnings declines, Ethyl's decreased 2% to $23.6 million, excluding nonrecurring items. Sales at Ethyl for the quarter increased 3% to more than $453 million.

At Texasgulf, which is a takeover target of Elf Aquitaine, earnings for the second quarter declined 3% from a year before to $57.6 million. Its sales, however, rose 16% to more than $278 million in the period. Despite the drop in earnings coupled with the increase in sales, Texasgulf continues to have one of the best profit margins, at 20.7%, of the 26 companies surveyed in the second quarter.

The biggest loser thus far is Philip A. Hunt, whose earnings dropped 43% in the second quarter to $1.2 million. The company's sales increased 3% to $28.6 million. □

New plan ties energy policy to marketplace

The Reagan Administration has announced a new national energy policy plan that is a significant departure from plans of the past. Gone is the emphasis on using the federal government as a lever to pry more energy out of U.S. industry. Instead, if everything goes according to the plan, adequate energy supplies will rely almost totally on the "marketplace."

The new plan reads more like an undoing of previous plans than a new program. It stresses the advantages of decontrol of petroleum prices and seems to indicate that the President will press for early decontrol of natural gas prices, now set for 1985. The plan also pulls away government support of synthetic fuel projects that are considered commercially viable and halts federal support of feasibility studies and cooperative agreements.

With respect to specific energy sources, the plan projects that the U.S. will continue to rely heavily on oil and natural gas, but says that supplies of both will be adequate. Oil production in the U.S. is not expected to decline, because deregulation likely will spur increased drilling activity. The same is expected to hold for gas supplies when their prices are freed. Also, the filling of the Strategic Petroleum Reserve has increased significantly with the aim of amassing a stockpile of 750 million barrels by 1989.

The two energy sources thought to be making the largest contribution to the nation's supplies are coal and nuclear energy. The federal plan says that the U.S. government controls four fifths of the known coal reserves in the western U.S. and, to spur coal development, the Department of Interior is working on transferring that control to the individual states.

The plan calls nuclear power plants "a safe, economical, and environmentally acceptable energy source." Consequently, the government is committing itself to removing the barriers to nuclear plant construction so this source may "compete fairly with other potential sources of energy supply."

The removal of regulations that impede energy production is important to achieve the Administration's goals. Admitting that some regulatory activity is needed to protect the health and safety of the public, it holds that not all present regulations are necessary. EPA regulations for water, air, and the outer continental shelf are being studied, as are Department of Energy rules and oil and gas leasing regulations.

The plan discusses at some length a number of other issues, such as the need for conservation—which is expected to continue as energy prices rise—the need to provide aid to the poor to meet high energy costs, and the value and contribution that can be made by the synthetic fuel industry. □

Keyworth confirmed as science adviser

Physicist George A. "Jay" Keyworth II had little trouble passing muster last week in his confirmation hearings for the post of White House Science Adviser. In what one observer called a "love feast," Keyworth appeared before only three members of the Senate Commerce, Science & Transportation Committee chaired that day by Keyworth backer Harrison Schmitt (R.-N.M.). Keyworth was Schmitt's hand-picked choice for the post.

Only 41 and coming from a relatively narrow background in nuclear physics related to the development of nuclear weapons, Keyworth neatly fits the ideological biases of an Administration heavily oriented toward weapons buildup. He was most recently physics division leader at Los Alamos National Laboratory in New Mexico. No questions were directed toward his role in national security policy matters, but he said he is in

CAEN staff photo

Keyworth: favors stronger relationship

favor of "strengthening the relationship" between the Defense Department and the space program.

Keyworth has backed off slightly from his statement in June that an outside President's Science Advisory Committee was unnecessary to scientific and technological advice to the President. He says he is looking into various options involving either a reconstitution of PSAC (abolished during the Nixon Administration), the appointment of ad hoc advisers, or a "mixture of the two."

In answer to a query by Schmitt, Keyworth said that he has indeed met David Stockman, director of the Office of Management & Budget, that he is a "strong admirer" of him, and that he expects to play a full and "equal" role in the development of the fiscal 1983 research and development budget. Development of the fiscal 1982 R&D budget excluded input from scientists.

He agrees with Schmitt that the problem of inducing young people to enter careers in science and technology is reaching crisis proportions but adds that he has no idea what it would take to motivate them toward technical directions. He says the state of research facilities in university laboratories is "disgraceful," fellowship money for promising students is inadequate, and that faculty is being lost to industry. He says he hopes to play a role in inducing industry to share some of the expenses of science education.

In energy policy, Keyworth says the government has "grossly mismanaged" the development of nuclear power that the U.S. developed in the first place and that the Administration soon will articulate its own posi-

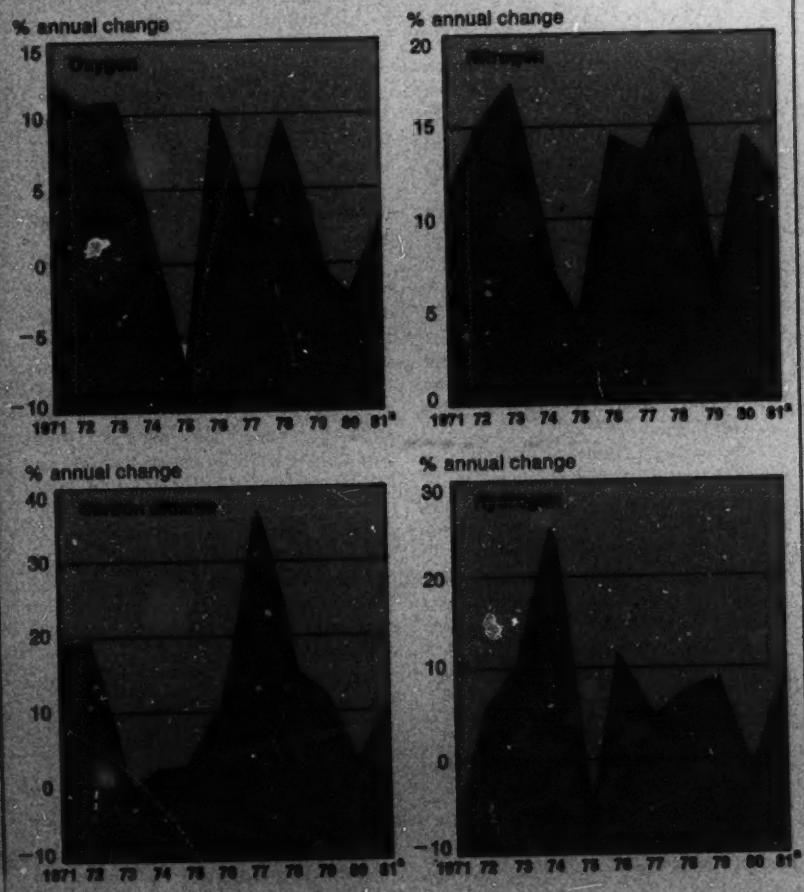
Industrial gases run into profits squeeze

Because of slackening economy and excess capacity, producers of oxygen, other key gases are cutting prices to hold onto or hike market share

In the long run, the industrial gas business is a good business to be in, one producer still says. But not last year and perhaps not this year. The economic slowdown last year, new entrants in the field, and plant capacity increases all have combined to hit gases hard.

As a result, the specter of a war for market share has reared its ugly head. Because of the industry slowdown and the resultant excess capacity, industrial gas producers have decided that this is the time to defend or increase market share. To do this, they are lowering prices—in some cases drastically. For example, the list price for liquid oxygen is 41.25 cents per 100 cu ft and for liquid nitrogen 38 cents per 100 cu ft. These prices are supposed to be for the largest users of each gas and therefore the lowest possible. However, industry sources say that the average price for liquid oxygen and liquid nitrogen taken together is about 35 cents per 100 cu ft, well below the list price for either.

Average annual growth for industrial gases was about 7.2% through past decade



a Estimated.

However, producers do not look for the narrower profit margins to last much longer, although they don't expect the kind of profits that they were getting in the late 1970's. They think industrial gases will be fully recovered from the doldrums of last year by the first quarter of 1982. And they say that as demand increases and excess capacity is soaked up, price cutting likely will cease.

Price cutting has hurt profitability particularly in the merchant market and to some extent in the entire gases market. Overall, gases remain in the black. This is because of the huge business in high-tonnage, or on-site, business where customers are on take-or-pay contracts.

The government's apparent cutback in the synfuels program has affected industrial gases' future development, but for different reasons in different gases. The effect will not always be bad. Oxygen producers may be hurt, as they were counting on selling huge quantities of oxygen from on-site plants that would have been needed for such projects as coal gasification and liquefaction. On second glance, however, some oxygen producers seem to be happy that the program has been slowed. "A crash program might have been disastrous," one producer says. "There aren't enough oxygen plants in the world to supply the kind of program that President Carter was talking about," he says.

Nitrogen to some extent is benefiting from the slowing of synfuels. The increased alternative search for oil is making tertiary recovery in old oil fields the fastest-growing nitrogen market.

And carbon dioxide is getting both pluses and minuses out of the slowdown. On the plus side, it, like nitrogen, is being used in tertiary oil recovery. But on the minus side, carbon dioxide producers were depending on huge new fermentation ethanol plants as a new source of supply for their raw material. These plants, to supply the gasohol market, also now may be partly held up.

For a more detailed 12-month outlook for oxygen, nitrogen, carbon dioxide, and hydrogen, see the following pages.

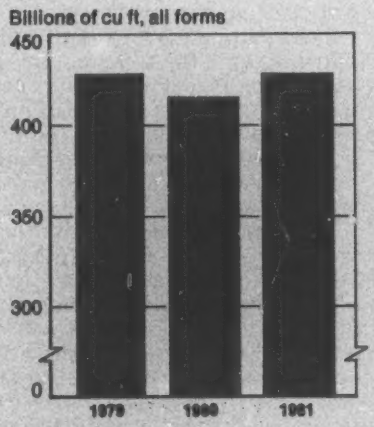
William Storck, New York

Oxygen

O_2

- ***Demand flat***
- ***Costs rising***
- ***Margins slipping***

PRODUCTION



HOW MADE

Separated from air at low temperatures

MAJOR USES

Primary metal manufacturing 30%, health services 13%, metal fabricating 33%

FOREIGN TRADE

Negligible

PRICES

41.25 cents per 100 cu ft plus shipping and equipment charges (merchant)

COMMERCIAL VALUE

More than $525 million for total production, 1981

For the second year in a row, U.S. production of oxygen slipped last year. In 1980 oxygen output was down 2.8% from the year before to 415 billion cu ft, according to figures from the Bureau of the Census. In 1979 production of all forms of oxygen had been down slightly, 0.2% from 1978 to 427 billion cu ft.

Thus far this year, the situation looks little better. U.S. production of oxygen for the first four months of 1981, the latest period available from the government, has fallen yet again. Through April, oxygen production amounted to about 142 billion cu ft, down 5.3% from the first four months of 1980.

The halt to growth has put oxygen behind nitrogen as the nation's most widely used industrial gas for the first four months of 1981, and producers say that oxygen will be hard pressed ever to catch up again.

The poor fortunes of oxygen are not hard to figure out. Since oxygen's primary markets are in the depressed steel industry, its output has sagged along with that of steel. Oxygen producers say that no turnaround can be expected until turnarounds show up in such end-use areas as construction and, especially, automobile manufacturing.

One of the problems in merchant oxygen in the past year and a half is that steelmakers are not buying the liquid. In normal times merchant oxygen is purchased by steel producers to supplement the oxygen that they get from on-site plants. Producers say that steel use of merchant oxygen probably will not turn around until later this year or early next year.

Although production was down during the first four months of this year, producers do not feel that that situation will continue for all of 1981. Oxygen makers say that for the whole year they expect about a 3% increase in production over 1980. This may be overoptimistic, however. To pull off a 3% production gain (based on the government figures) producers would have to increase output about 7.7% for the rest of the year over the last two thirds of 1980.

The turndown in oxygen, and especially in merchant oxygen, has brought downward price pressure to the industry. The list price of merchant oxygen now is 41.25 cents per 100 cu ft, about 10% higher than last year's price. This price is theoretically for the largest-volume users. It does not include shipping charges and charges for storage and handling equipment supplied to the customer by the producer.

In spite of the 10% rise in the list price this year, producers say that there is deep discounting in the merchant market. They add that, since each customer's contract is separately negotiated, the price can vary greatly.

But even more important than this, producers believe that the term "market share" has taken on a sinister meaning. They say that as demand has fallen for the past year and a half some of the air separation companies have lowered prices to try to grab a bigger slice of the pie. Thus, increased competition in oxygen is squeezing profit margins.

Add to this the increased cost pressure from rising energy prices. Oxygen producers estimate that about 60% of the cost of producing both oxygen and nitrogen is for energy, specifically electricity. Electricity rates have been going up steeply for the past few years. Although the rate increases this year have not matched those of 1980, which were up 30% in some parts of the country, they have continued to climb. In some places rates are up 20% over levels last year.

Shipping charges also are contributing to the squeeze. Shipping charges have not increased since last year in spite of increased shipping costs, producers say.

Thus, producers say that margins are so squeezed that the products from air separation plants are selling at prices way below what would be needed to justify reinvestment. In spite of that, plant building is still going on, and many producers are worried that there may be too much expansion. As a result, larger producers seem to be more careful about where they put plants than they have been in the past. In some cases, they are just replacing older plants with newer, more efficient ones. They also are piggybacking merchant capacity onto on-site plants whenever possible to help reduce risk.

Producers say that there may be a turnaround in this profit margin shrinkage, but they also think that profitability will not get back soon to where it was in the golden days of 1977 and 1978.

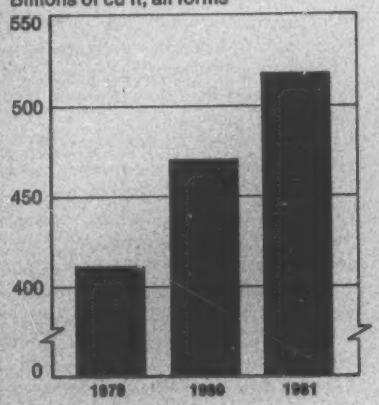
N_2

Nitrogen

- ***Growth good***
- ***Prices up***
- ***Profits squeezed***

PRODUCTION

Billions of cu ft, all forms



HOW MADE

Separated from air at low temperatures

MAJOR USES (merchant)

Blanketing atmospheres—chemical processing 14%, electronics 15%, metals 5%; freezing agents 21%, aerospace 8%

FOREIGN TRADE

Negligible

PRICES

38 cents per 100 cu ft plus shipping and equipment charges

COMMERCIAL VALUE

About $550 million total production, 1981

Nitrogen became the largest-volume industrial gas last year with 472 billion cu ft produced, compared to 415 billion cu ft for oxygen, the traditional leader.

And because of the respective growth rates of the two gases, producers say that oxygen probably will never regain the lead. In fact, according to producers, nitrogen has been the leader in the important merchant market for some years.

The reason that oxygen will not overtake nitrogen is that there are few if any new growth markets for oxygen, and there are for nitrogen. Nitrogen output of 472 billion cu ft last year was 14.3% higher than in 1979. The year 1979 was somewhat slow for the gas with only a 5.4% increase from 1978.

Producers say that they were somewhat surprised by the growth of nitrogen in 1980. In part, it came about because of new uses. One new rapidly growing use is showing the best growth of all nitrogen uses: tertiary oil recovery in old oil fields. The gas is used in oil fields to maintain pressure in the wells, a job formerly done by natural gas.

The oil field use is having an effect on both merchant and pipeline nitrogen. Merchant nitrogen is used at a well until it proves itself. Then the oil producer commits funds to build a tonnage or on-site plant.

The refrigeration use of nitrogen also did well last year, and its use as a blanketing atmosphere for metal production did not slow so much as producers had anticipated, in spite of the slowdown in metalworking. This may be because many nitrogen uses are in high-technology areas, which were unaffected by the recession last year.

So far this year, nitrogen seems to be continuing its growth, although not so fast as in 1980. Production of nitrogen through the first four months of 1981 increased 2.7% over the same period last year to more than 159 billion cu ft. As with oxygen, nitrogen will have to have a good final eight months to bring it up to the producers' forecast of 12% growth for the year. Nitrogen may not have much trouble doing this, however, since, like oxygen, it was the final nine months of the year that brought suffering in the industry last year. From here on out, year-to-year comparisons will look good.

Producers say that nitrogen growth is much less dependent on the economy than oxygen growth. Besides its increasing use in recession-resistant high-technology areas and in the oil field area, nitrogen grows largely because it continues to be substituted for natural gas. So as the price of natural gas increases, this substitution may accelerate.

In spite of its growth, however, nitrogen is plagued with many of the same pricing and competitive problems as is oxygen. Like the oxygen price, the price of nitrogen has increased 10% during the past year. The current list price for the largest users of merchant nitrogen is 38 cents per 100 cu ft, against about 34.5 cents at this time in 1980. However, again like oxygen, there are huge discounts varying from customer to customer and region to region. As for oxygen, production costs are increasing rapidly, with the two—costs and pricing—combining to squeeze profits much more than oxygen producers would like.

So, whereas last year producers were considering new pricing policies, this year those considerations seem to have been scotched by the competitive nature of the marketplace, in which some companies are attempting to increase market share.

And again, distribution is causing problems. Shipping charges have not increased to keep pace with rising fuel, labor, and other costs. And distribution costs are about 50% of the cost of getting the gas to the customer.

The cost of distribution is shrinking the range that nitrogen, as well as other gases, can be shipped. Traditionally, this radius averaged 200 miles from the air separation plant, but this figure is declining as more plants are built in industrialized areas and as the cost of shipping increases.

Capacity is no problem to nitrogen producers, since about four times as much nitrogen can be produced in an air separation plant as can oxygen. However, this big production potential is just adding to the problems of producers as they try to find markets.

Overall, the outlook for nitrogen producers is still for expanding markets and good growth, but with continued profit shrinkage for some time.

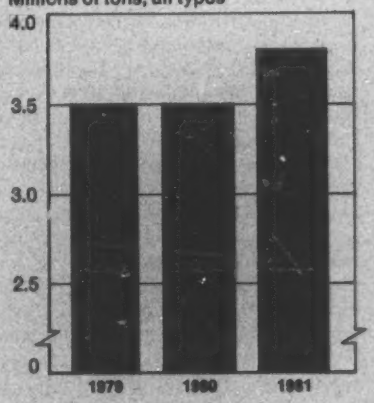
Carbon dioxide

CO_2

- ***Growth slow***
- ***Prices up moderately***
- ***Feedstock tight***

PRODUCTION

Millions of tons, all types



HOW MADE

Recovered from synthesis gas in ammonia production, recovered as by-product in substitute natural gas production, recovered as by-product from fermentation ethanol production, recovered from natural wells

MAJOR USES

Refrigeration—food 37%, industrial 5%; beverage carbonation 20%; other industrial uses 22%

FOREIGN TRADE

Negligible

PRICES

About $64 per ton for largest users; prices vary by region

COMMERCIAL VALUE

More than $145 million for total production, 1981

Carbon dioxide production in the U.S. was flat last year, but producers are expecting better things of 1981. It looks as if they are going to get their wish.

Production last year increased only 0.3% to 3.54 million tons from 1979, well below the gas's five-year growth rate of 13.9% and its 10-year growth rate of 12.1%.

But so far in 1981, things seem to be getting back on track. According to government figures, U.S. production of carbon dioxide through April was up 16% to 1.22 million tons. This is the highest growth of any of the four big industrial gases so far this year.

Thus, carbon dioxide is the one gas that may not have to work very hard to come up to producers' expectations in 1981. Producers are forecasting growth of 10% for all of this year over 1980.

Like nitrogen's, carbon dioxide's growth is being helped by increased use in old oil fields, where it is used in tertiary recovery. And, as for nitrogen, this is helping the merchant liquid market in that liquid must be used until carbon dioxide is proved feasible for each well. The test for feasibility can take as much as 12 to 15 tons of liquid carbon dioxide per day over many months.

After feasibility is proved, then the oil field operator switches to pipeline carbon dioxide from large-scale plants.

However, in spite of its rapid growth in oil field work, carbon dioxide's traditional markets have been slowing, producers say. The refrigeration use of carbon dioxide did not meet expectations last year, although for the long term, this market likely will continue to expand. Producers say that carbon dioxide will continue to displace some nitrogen in food freezing as the cost of electricity, and thus the price of nitrogen, increases.

In fact, the price of carbon dioxide is not rising nearly so fast as that of other industrial gases. The current price, which went into effect in the past two months, is $64 per ton (for the largest-volume users). The $64 price is up only 5% from the previous price, and there is some discounting and softness on a regional basis.

The fastest growth for carbon dioxide is occurring in the South—particularly on the Gulf Coast, but not limited to it—and on the West Coast. In the South, the growth is spurred mainly by the oil and chemical industries, but it is also being helped by some industries that are moving south from other areas of the country and who are traditional carbon dioxide users. On the West Coast, much of the growth is coming from use in the oil industry.

Although growth is good on the West Coast and the Gulf Coast, producers say the Midwest is especially weak. Part of the problem there, they say, is a new 200 ton-per-day plant opened last year by Archer-Daniels-Midland that gets its carbon dioxide from fermentation ethanol.

That this particular plant should be causing problems is somewhat of a paradox in the carbon dioxide market. Producers, who have been worried about lack of feedstock availability, have been pinning their hopes to some extent on fermentation ethanol as a source. The problems in the Midwest are further compounded because some food freezing operations are moving south.

There do seem to be long-term problems in just where carbon dioxide producers will get their feedstock. The big source in the past has been ammonia plants, but growth of ammonia is much slower than that of carbon dioxide. Producers were hoping that the government's energy programs would go through, giving them new sources from substitute natural gas as well as from fermentation ethanol, which would be used to make gasohol. Ethanol alone would have made the supply problems go away, they say. These hopes have been dashed by President Reagan's scaling down of the synfuels program, and producers now are openly talking about running out of supplies sometime in the future.

Even now, producers say sources of supply are short and they say the situation will only get worse. In spite of the short supplies, producers say that pricing has not kept up with costs.

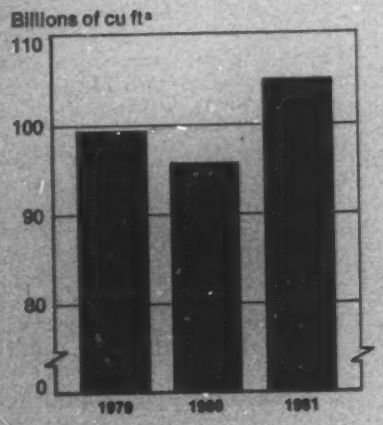
Nameplate merchant carbon dioxide capacity is about 15,600 tons per day, but this figure is somewhat illusory. If related ammonia production is off, then the effective capacity of carbon dioxide plants suffers. Thus, effective capacity is now about 85% of nameplate, and this will shrink as the year goes on and the demand for ammonia decreases.

H_2

Hydrogen

- *Production recovering*
- *Market expanding*
- *Prices up*

PRODUCTION



[a] Excluding captive production.

HOW MADE

Steam reforming of natural gas

MAJOR USES

Chemical processing 63%, metallurgical uses 37%

FOREIGN TRADE

Negligible

PRICES

98 cents per 100 cu ft in 13,000-gal lots (liquid)

COMMERCIAL VALUE

About $150 million for total merchant production, 1981

Hydrogen has been one of the bright spots in the U.S. industrial gas business—that is until last year. In 1980, however, hydrogen production fell 3.2% from 1979 levels. This is quite a change from the gas's 10-year growth rate of about 6%.

This growth rate, alone, however, did not make hydrogen's reputation for profitability. Rather it was the relative lack of competition and modest growth of producing capacity that has made merchant hydrogen a good product to be in. And producers believe that the growth rate will increase—to as much as 10% per year.

There are essentially only three producers of liquid hydrogen in the U.S. —Union Carbide, Air Products, and Airco, the U.S. subsidiary of Britain's BOC International. Union Carbide and Air Products dominate the market.

Merchant hydrogen is just a small part of all of the hydrogen produced in the U.S. Some industry experts have estimated that total production of hydrogen far outstrips any other industrial gas on a cubic-foot basis. This is because many users of hydrogen produce their own gas for captive use. These sources of hydrogen are largely unknown and thus not counted in the government production figures. Therefore, no one knows just how much hydrogen is produced or even how many producers there are. This segment has been estimated to be at least as much as 10 times as large as merchant hydrogen output, however.

Merchant hydrogen production suffered last year because it is closely tied to two highly cyclical products. About 63% of merchant hydrogen production goes to chemical processing for such products as plastics, pesticides, and chemical intermediates. The other 37% goes to metal processing where it is mixed with nitrogen to form blanketing atmospheres.

Since both chemicals and metals suffered last year, it is no wonder that merchant hydrogen production declined. In fact, merchant hydrogen production is a lagging indicator for the economy. Last year hydrogen production did not start to decline until after the recession had begun.

And since the chemical and metal economies have not yet improved, neither has hydrogen production. U.S. production of hydrogen was off 3.8% through the first four months of 1981 to 32.1 million cu ft. This number is only roughly correct, since it takes into account some hydrogen gas that is sold on the merchant market. It rather should be used as an indication of the way the market is going.

The price for hydrogen seems to be increasing, although price seems to be uncertain, too. Since, like other industrial gases, contracts include widely varying prices, the average for the industry is largely unknown. The best guess is that hydrogen currently is selling at about 98 cents per 100 cu ft in 13,000-gal lots. This excludes equipment and shipping charges. Other estimates have put the price about 10 cents higher. However, these prices are discounted and, further compounding the problem, in some cases energy surcharges apply.

But, if it is assumed that the current list price is 98 cents, this represents an increase of about 7.7% from a year ago. It also means that the price of hydrogen has increased almost 30% in the past three years.

Even though there is discounting now, the small number of producers almost guarantees a more orderly marketplace for hydrogen than for other industrial gases. For one thing, there is not the spate of new capacity as in the three other gases. Merchant hydrogen capacity is still about 128 tons per day, the same as it was at this time last year, according to industry sources.

Two new plants will be coming on stream to serve the U.S. market. Air Products' new plant at Sarnia, Ont., although not a U.S. plant, will be sending most of its products into U.S. markets. This plant will come on stream sometime this year, and will be the first new capacity serving U.S. markets since 1979. Union Carbide also is building new capacity at Niagara Falls, N.Y., which will be on stream in 1982.

Transportation costs also are becoming problematical. In the past, liquid hydrogen has been shipped up to 1000 miles from the plant. Although it still is possible to do this, producers feel that they had better look to ways of cutting this overhead. They say that in the future plants will be built closer to areas where the merchant hydrogen is needed.

Japan's caustic-chlorine producers hurting

Problems plaguing producers range from higher costs for raw materials and energy to stagnant markets; demand may improve in second half

Japanese caustic-chlorine producers are struggling. The industry is saddled with an array of problems, stretching from raw materials clear through to the market that is making the present uncomfortable and the future uncertain.

Minimizing, rather than eliminating, these problems is about the best that the industry can hope for.

Japanese caustic-chlorine producers depend entirely upon imported salt for their raw material. Prices have risen significantly and figure to continue increasing. The industry, of course, is energy-intensive. And, in Japan, which depends largely upon imported fuel, energy costs are staggering. As a result, production costs are high.

The marketplace is a shambles, too. The business slump that Japan is just crawling out of has kept caustic demand down. But stagnant demand, coupled with massive imports of chlorinated products, has made the chlorine market even worse.

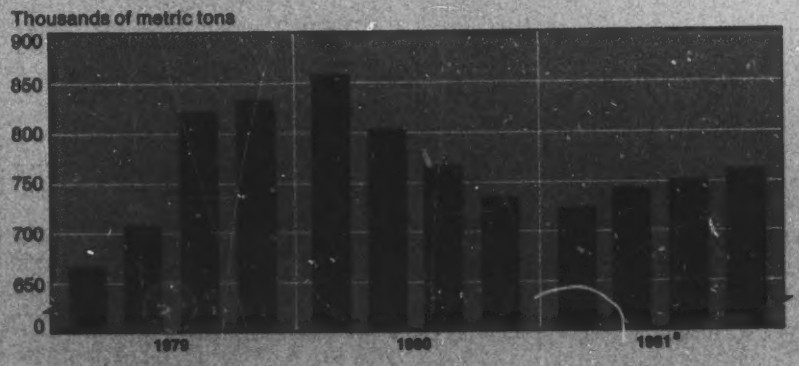
Thus, chlorine has dictated operating rates of electrolytic plants. At the end of last year, the industry was running at an average 63% of capacity. Liquid chlorine plants averaged a dismal 49% of capacity. And the irony is that, because of chlorine, caustic supply has been tight in Japan even in the face of a poor market.

To complicate matters, caustic producers will have a tough time finding enough material to satisfy the export market that they have been emphasizing recently to compensate for the poor domestic market. Caustic exports jumped 58% in Japan's fiscal 1980 to 192,000 metric tons. But in fiscal 1981 (ending March 1982), caustic availability probably will limit exports to 165,000 metric tons.

Now, even caustic imports are becoming a problem. They increased 55% last year to 34,000 metric tons, primarily because Dow Chemical Korea started caustic production in mid-1980 and began shipping it to Japan. This year, caustic imports likely will increase to about 45,000 metric tons.

On top of all this, Japanese caustic-chlorine producers are faced with a massive capital-spending program to comply with the government-mandated changeover from mercury cell plants to diaphragm and ion-exchange membrane units. So far, the industry has converted about two thirds of its capacity and expects to complete the conversion by the end of 1984.

Japanese quarterly caustic output likely will rebound this year, following sharp falloff in 1980



a Third and fourth quarters are estimated. Sources: Ministry of International Trade & Industry, industry estimates

The situation can hardly get worse for Japan's caustic-chlorine producers. "But it won't get a helluva lot better, either," says one expert familiar with the plight of the industry.

At the very least, producers are hoping that Japan will shake off the economic slump that has gripped the country and that demand in Japan will improve in the second half of the year. Even so, production of both caustic and chlorine probably will be down about 6% compared to last year.

Even if this should happen, producers will chalk up 1981 as a recovery year, despite the dismal annual comparison with 1980. Last year, Japanese caustic output, for instance, was 3.16 million metric tons, up 4.5% from 1979. But that increase came on the strength of an exceptionally strong first quarter. After that, it was downhill all the way for Japanese caustic output. The same is true of chlorine.

This year, however, quarterly production of both caustic and chlorine likely will increase as the year goes on, even though the figures won't come close to matching those of first-quarter 1981.

Over the long haul, the industry expects caustic demand to grow an average of 2.5% per year and chlorine demand to increase 3.5% annually. To close the gap, producers can expand caustic exports, or import more chlorine derivatives, or they can do both.

They also will try to get more leverage in negotiating prices for imported salt. Currently, most of Japan's salt comes from Mexico and Australia. But Japanese producers are eyeing China as a third major source.

Another tactic that already is becoming evident is overseas investment. Japanese producers probably won't build much more than replacement capacity in Japan for caustic and chlorine. Instead, they will build overseas where energy and raw material costs are lower. The Dow-Kanegafuchi-Mitsui Toatsu joint venture to make derivative ethylene dichloride in Canada is only one example.

Earl Anderson, New York

Synfuels and coal conversion: what cost?

Forecasts differ over break-even point of coal conversion; oil costs, actual value of various fuel types cloud issue

Joseph Haggin
C&EN, Chicago

The success of a future synthetic fuels industry is keyed to the prices of petroleum and natural gas. Most synfuels are being developed as substitutes for petroleum and gas derivatives and, therefore, must follow the lead of petroleum and gas in energy markets.

Predicting this lead is difficult. But the net result of recent estimates is a more or less consistent appraisal by oil and gas companies of the general economic climate for a future synfuels industry. There also has been a substantial revision in the belief that the only way to rate fuels is by their heat content.

On the one hand, the economic machinations of the Organization of Petroleum Exporting Countries cloud the future for synfuels. And there isn't a way to predict confidently economic trends in the fuels industry. Offsetting these uncertainties somewhat, however, are more realistic current estimates of the technical and economic probabilities for synfuels. As the era of synfuels gets closer, the estimates get tighter. And although some predictions in Congressional reports are pessimistic, they are being refuted by a growing portion of the technical community.

A survey of various oil companies finds that they more or less reflect the opinions of a few major firms. One common thread is the effect of inflation. Another is the cost of plant and equipment and the difficulty of obtaining capital.

Pervading almost every scenario is the influence of oil prices. This has been referred to as the phenomenon of the "receding break-even point." Five years before the Arab oil embargo of 1973, there was a consensus that the price of oil would have to double to make coal liquefaction and/or gasification economically attractive. Five years after the embargo, a similar consensus said exactly the same thing: The price of crude oil more than tripled over the interval, but somewhere off in the future there is a break-even point in costs that will make synfuels economically possible.

The phenomenon of the "receding break-even point" cannot be blamed entirely on inflation. Prices of coal, gas, and oil all have risen faster than the inflation rate. There seems to be a "historical force" at work in the opinion of some observers. Others think that the explanation is simply that deregulation finally has restored oil and gas to a truly competitive position.

There is also the phenomenon of market penetration. Quite a few models have been built for the penetration of a well-established market by a new competitor. In the present case, the well-established oil and gas market is being approached by synfuels, or more specifically by coal, shale, tar sands, and other raw materials. A number of models suggest that if and when synfuels can capture about 5% of the oil and gas markets, they may be established well enough to be considered secure. If secure, the competition between synfuels and conventional fuels then would become an economic adversary relationship that would bring the receding break-even point rather close. In fact, there are numerous examples of market penetrations by new competitors that suggest that a 5% share of a market is virtually a guarantee that the newcomer eventually will take over the market.

The problem of receding break-even points has appeared again in a study recently completed for the House Committee on Science & Technology. The principal author, Robert V. Jelinek, a professor at the State University of New York's College of Environmental Science and Forestry, Syracuse, stipulated that it was necessary to ascertain the real relationship between synfuel costs and rising oil prices. This was in response to the need to establish what the required selling price for future synfuels would be.

An examination of seven typical synfuel processes showed that as oil prices rise, the projected cost of synfuels from new plants using foreseeable technology rises proportionately. No matter how high the price of oil rises—even to $100 per barrel—a new plant built subsequent to the arrival of oil at that price would not be economic; that is, the necessary selling price of the synfuel always would be higher.

Of the processes examined in the Jelinek report, Fischer-Tropsch was

Synthane, Hygas most complex processes

Process	Complexity[a]
Synthane	6
Hygas	6
Bigas	5
CO_2-acceptor	4
H-Coal	4
Westinghouse syngas	3
Solvent-refined coal—SRC-I	3
Lurgi	3
M-Gasoline	2
Fischer-Tropsch	2
Exxon Donor Solvent	2
Solvent-refined coal—SRC-II	1

a Empirical estimate, with more complex processes having the higher numbers. Source: Engineering Societies Commission on Energy Inc.

Highest-value synfuel product is electricity

Product	Value factor[a]
Electricity	2.60
Propane	1.08
Butane	1.07
Methanol	1.00
All fuel gases	1.00
Methyl fuel	0.96
Gasoline	0.90
LPG	0.86
Tar oil	0.85
Diesel fuel	0.82
Naphtha	0.82
Fuel oil	0.56
Solvent-refined coal solid	0.50
Char	0.47

a Indicates market value relative to premium gasoline, with an assigned value of 1.00. Source: Engineering Societies Commission on Energy Inc.

Oil companies speculate on economic climate for synfuels

Except to say that oil and gas prices probably will rise over the long term, there is no way to predict economic trends in the fuels industry with confidence. Still, oil companies will be among the chief proponents of synfuels and a number of them have furnished some prognostications on the near-future economic climate for synfuels.

Shell Oil Co., for example, in a 10-year forecast, expects economic growth to be roughly that of the mid-1970's, with inflation dropping from the 8 to 10% range in the early 1980's to less than 8% by 1990. Population growth will drop to less than 1% per year and the labor force will grow at less than 2% per year. Industrial regulation will continue more or less as is, with emphasis on the allocation of fuels to preferred uses. Federal leasing policies, onshore and offshore, will continue to hinder the development of these reserves of energy. Shell does not expect the general public to become much more concerned with energy than it is now, and as a result prolonged licensing procedures for energy plants will continue.

Publicity to the contrary, says Shell, the private sectors of the economy have good conservation records, and the 1980's will see the encouragement of synfuel substitutes. The introduction of synfuels will be slow, with coal and shale providing about 1.7 million barrels per day of oil equivalent in 1990.

Exxon has a somewhat more optimistic expectation of mineral leasing on federal lands. Government incentives, Exxon says, probably will lead to increased oil and gas production from federal reserves, and a gradual moderation of restrictions on nuclear licensing also will help energy matters. However, a problem probably will develop as capital is diverted to things other than labor-saving equipment. This likely will slow the growth of gross national product and individual productivity.

Exxon expects that another problem for synfuels will be a moderating of the drive toward a better environment to permit the greater use of coal, both as a primary fuel and as a feedstock source. Oil imports will be available as needed, but energy prices will increase at roughly the inflation rate. Exxon expects GNP to grow at about 2.7% per year, which is half the rates of the 1960's and early 1970's.

The global political climate during the 1980's will remain unsettled according to forecasts by Conoco. There is thus a likelihood of disruptions in world oil markets again, with adverse effects on conventional fuel supplies from abroad. The unsettled climate also will result in greater acceptance of synfuels, which will not be offered in great quantities in the 1980's but which will appear nonetheless.

Conoco foresees tremendous obstacles to be faced by the first commercial synfuel venture, the biggest probably being developing the capital to finance it. Considering all the problems, Conoco is estimating that by 1990, gas from coal will be available in quantities up to 175 billion standard cubic feet per day, coal liquids at 65,000 bbl per day, shale oil at 175,000 bbl per day, and fuels from biomass at 130,000 bbl per day.

Cities Service is considerably more optimistic on the immediate contributions from synthetics. Even though shale oil recovery technology isn't commercial, about 600 billion bbl is recoverable in the western U.S. and the rate of development suggests that the U.S. could produce 360,000 bbl per day by 1990 with an investment of $20,000 per bbl per day of capacity. The oil price probably will be about $25 per bbl in 1979 dollars. Much will depend on the government's efforts.

As far as coal conversion is concerned, the technology is further along in general, but the technology may not be just right for the U.S. Cities Service believes that although direct burning of coal may be the cheapest way to use the resource, gasification and liquefaction offer advantages. A gas distribution network is already in place, pollution effects are minimal, and the need for prime transportation fuels may be decisive in the overall development of synfuels.

According to Cities Service, the key to synfuels development is hydrogen enrichment of coal. Hydrogenation processes are available and some of them are already commercial. Economic and regulatory problems, particularly with strip mining, appear to be the chief impediments.

Cities Service suggests that it is unlikely that synthetic crude oil will be of consequence this century. Its best estimate is that as much as 100,000 bbl-per-day equivalent might be available by 1990. The capital requirements easily could reach $40,000 per bbl per day of capacity and the cost of the oil would be $40 per bbl. Other energy sources, including what the company terms "exotics," are not considered significant enough to speculate about.

the most expensive with costs about double those of H-Coal, Exxon Donor Solvent, and Lurgi processes. Both methanol and ethanol for fuels would be more expensive than coal hydrogenation liquids, with ethanol being more costly than methanol. Shale oil extraction by the Tosco-II process would cost the least, provided high-quality shale were available.

Jelinek's analysis notes that in recent times, oil and gas have been the dominant sources of energy and it seems to him logical that production costs should track closely with the price of energy. Capital costs, on the other hand, clearly dominate the cost picture for synfuels. The rather pessimistic conclusion is that synfuels will be economically attractive only as long as oil prices continue to rise. If oil prices stop rising, then no synthetic fuels venture can possibly be profitable.

In view of the guardedly optimistic expectations of the various oil companies, it would appear that on the basis of Jelinek's analysis synfuel projects are foredoomed unless they can be started immediately in a time of expected price escalations for oil.

That pessimistic viewpoint isn't shared equally by all observers. A more moderate view has been expounded by Harry W. Parker of the Engineering Societies Commission on Energy Inc. (ESCOE), a joint venture of several professional engineering societies. Parker distinguishes between bulk energy and convenience energy. Bulk energy is, for the most part, coal and gas for industrial use. Convenience energy is the energy used for transportation fuels, home heating, and light industry. Bulk energy is much less susceptible to market fluctuations, is usually subject to stable long-term contracts, and is, thereby, a relatively stable quantity. Convenience fuels, such as gasoline, are less stable in the marketplace and respond quickly to market pressures.

The important distinction is that Jelinek appears to assume that all Btu's were created equal and can be priced accordingly, whereas Parker assumes there are at least two distinct classes of fuels that can be priced differently. Another analysis by an ESCOE group has carried the idea even further by assigning a product value to all the various products of a synfuels complex.

The ESCOE study examined 14 coal conversion processes for a synfuels industry of the future. The basis was a need for an alternative to the established fuels industry, the third

time that the problem has appeared in this century. In every previous case the synthetic fuels industry was foredoomed by a cheaper alternative energy base.

In its examination, the ESCOE group encountered the matter of evaluating processes on the basis of dollars per Btu. This is a useful approach, it noted, for a single-product plant, such as SNG for pipeline use. However, this approach is very unsatisfactory and unrealistic when a variable product slate issues from the plant. The ESCOE group noted that even with federal price controls, gasoline has a wholesale price higher than that of home heating oil, which, in turn, has a wholesale price higher than that of fuel oil. A fixed price per Btu of heating value would invert the price ranking of these three fuels on a volumetric basis, since heating oils have a higher heating value per gallon than does gasoline.

The conclusion of the study was that any analytical method that does not account for inherent differences in market value and in market preferences is not fruitful. The ESCOE group, therefore, developed a product value index for estimating product prices. This approach has considerable value in estimating synfuels potential, although the confidence level may not be so high as would be desirable.

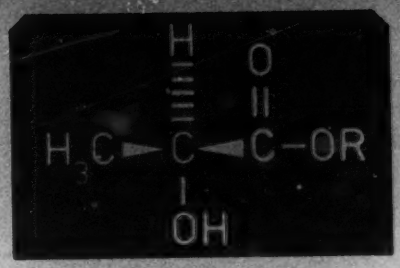
The 14 processes to which these evaluation techniques were applied are either already commercial or are well along in R&D. The processes are not merely combinations of other processes but are distinct, recognizable processes. Other criteria for the synfuel process evaluation are the process complexity, which is somewhat empirical and takes into account both physical complexity of the hardware and the complexity of the reaction system, and the process efficiency, which is defined as the higher heating value of the products divided by the energy input.

The 14 processes evaluated by the ESCOE group show about the same cost trends as observed in other evaluations. However, there is a considerable difference in the projected absolute costs when compared to many of the other evaluations. There are also some unique features of nonoil resources that eventually may break the pattern of the "receding break-even point."

The conventional wisdom—that the cheapest thing to do with coal is to burn it, and that as long as gases and liquids from coal are merely substitutes for less expensive oil products, oil will drive the energy economy—seems irrefutable. However, burning coal doesn't necessarily generate the most profit, nor is the simple substitution of coal products for oil products necessarily the most desirable way to design a synfuels industry. The coal refinery of the future will have its own unique product slate, probably resembling only vaguely that of today's oil refinery. □

PPG modernizes chlorine-caustic facilities

With expansion of its chlorine-caustic facilities at Lake Charles, La., completed about a year ago—bringing total capacity at the site to 3000 tons per day of chlorine and 3400 tons per day of caustic soda—PPG Industries now is modernizing some of its older units. New giant chlorine cells (above) are replacing outmoded diaphragm cells. The new units, PPG says, will reduce the amount of energy required to produce chlorine and caustic soda about 25%. The updated facilities are designed to use some of the hydrogen produced to power the cells. PPG expects to complete its modernization in 1983.



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Facts & Figures for Chemical R&D

Research and development is vital to the U.S. and its economic prosperity and social health. This year, spending on R&D is expected to total about $69.1 billion. And according to National Science Foundation projections, R&D spending in 1982 is expected to increase 14% to $79.0 billion. This funding supports the work of more than 650,000 scientists and engineers.

Exactly how much money goes into chemical R&D is not known. C&EN, however, estimates that government agencies, industry, and academic and other nonprofit organizations spend more than $5.5 billion on chemical R&D.

According to NSF's latest biennial survey of scientific and engineering manpower, 212,400 physical scientists were employed in the U.S. in 1978, including 143,700 chemists, up from 201,400 physical scientists and 133,500 chemists in 1974.

C&EN publishes on the following pages its third annual report on R&D spending and manpower, with special emphasis, where possible, on R&D in chemistry and chemical engineering. The data indicate, among other things, where the funds come from, who does the work, and what types of R&D are performed. They show, for example, that, before 1979, 50% or more of all R&D money came from the federal government for defense-related, space-related, or civilian-related R&D. Since 1979, however, more than half of all R&D funds have come from nonfederal sources.

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Where academic institutions get R&D funds and how they use them. What schools spend most. Degrees in chemistry and chemical engineering

Of great concern to many observers of science and technology has been the decline in spending on R&D relative to the U.S. gross national product. In 1967, 2.9% of GNP went into R&D. The percentage had dropped to 2.2% by 1978. This decline was caused by a slowdown in the growth of federally supported R&D programs. Since 1978, however, the percentage has risen gradually and will reach an estimated 2.4% in 1981. This increase is attributed partly to a leveling off in GNP during the past couple of years. Another factor has been the nation's increased spending on R&D in energy.

The U.S. spends more on R&D than do all other western countries and Japan combined. On the other hand, the U.S. ranks second to West Germany in R&D spending as a percentage of gross national product. The U.K. and Japan rank close behind the U.S.

Clearly, inflation is having a serious impact on U.S. R&D funding. Although total R&D funding in current dollars is expected to increase 13% from 1980 to 1981, in constant dollars the gain is likely to be only 3%.

And whether the next couple of years will see even that much growth is far from clear. Much depends on the policies of the Reagan Administration.

On the one hand, the Administration has been signaling a change in direction for federally supported R&D. Although apparently it still considers basic research a fit invest-

ment for federal funds and is backing increased R&D with military applications, it appears much colder regarding applied research and development in general. The message from Washington now seems to be that funding for these areas should shift more toward the private sector. The overall effect, therefore, is likely to be markedly slower growth in real spending for R&D as a whole.

On the other hand, if the Administration manages to curtail inflation—and that is one of the prime reasons for budgetary restraint, in R&D and elsewhere—then the current cost erosion of the R&D dollar will ease as well. But the verdict is still out on the success of current inflation control programs.

Over the past decade, the nation has steadily increased its support of basic research, in terms of current dollars. Because of inflation, however, spending for such research remained almost unchanged at $3.7 billion to $3.8 billion in constant (1972) dollars between 1971 and 1976. Since then, the federal government, which supports about 70% of the nation's basic research, has been expanding such research funding in constant dollars from $3.9 billion in 1977 to $4.6 billion in 1980.

Total federal funding for R&D is expected to climb 11% to $35.5 billion in fiscal 1981, largely because of a 20% rise (from $13.8 billion to $16.6 billion) in R&D spending by the Department of Defense. Much of DOD's funding will go for R&D on missile and communications systems, particularly for the Air Force.

R&D funding by the National Aeronautics & Space Administration increased 6% to an estimated $5.4 billion in fiscal 1981. The biggest reason for this growth was the space shuttle program.

Funding of R&D by the Department of Health & Human Services rose 3% to $3.9 billion in fiscal 1981. Some 84% of this money is spent by the National Institutes of Health. In 1981, the institutes that showed the greatest gains in R&D funding are the National Institute of Environmental Health Sciences (up 13%) and the National Institute of Arthritis, Metabolism & Digestive Diseases (up 9%). The National Cancer Institute, which is NIH's largest institute, saw almost no expansion in its 1981 program.

Industrial support of R&D rose 13% from $38.0 billion in 1979 to an estimated $42.8 billion in 1980. One reason for this increase is heightened interest in energy R&D. Companies have been searching for new sources of energy and for new ways to improve the efficiency of energy use.

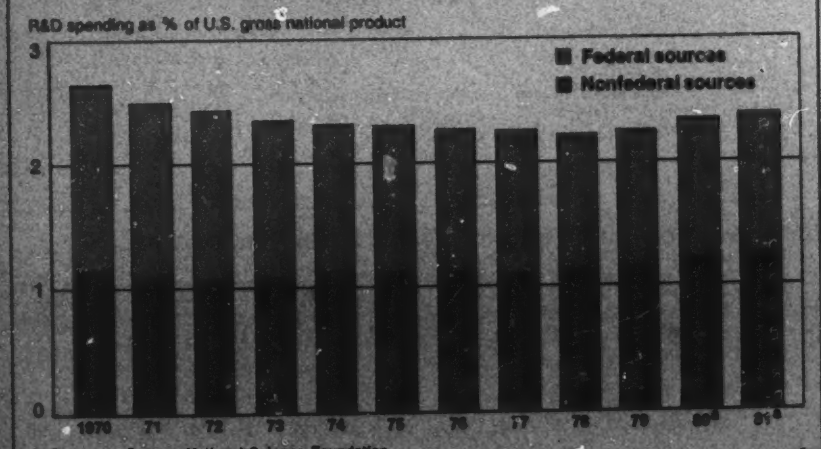
Spending for R&D in the chemicals and allied products industry increased 14% from 1979 to $4.6 billion in 1980, C&EN estimates. After adjustment for inflation, however, the gain was only 5%. In the industrial chemicals industry, R&D spending rose 14% to an estimated $2.3 billion last year. This also amounted to a real gain of 5%.

The pace of R&D continued active in the drug industry. R&D spending among drug companies rose from $1.63 billion in 1979 to about $1.9 billion in 1980—a gain of 16%. The products of greatest R&D interest in this period were anti-infective agents, cardiovascular drugs, and drugs to treat the central nervous system and the sense organs.

Spending for academic R&D climbed 15% to an estimated $6.0 billion in fiscal 1980. But that amounts to only 6% after factoring out inflation.

Spending for research in chemistry at colleges and universities rose 15% to an estimated $230 million in fiscal 1980. The increase likewise was only 6% in constant dollars. □

R&D's share of GNP has risen slightly in past few years



a Estimates. Source: National Science Foundation

1 R&D Section one Overview

An increase of 13% seen this year in spending for R&D

Industry sets the growth pace, both as a funder and a performer of R&D, as the federal share of total dollars continues to decline

Between 1971 and 1981, total spending on R&D in the U.S. grew at a rate of about 10% a year. When inflation is taken into account, however, the annual increase falls to only about 2%. Thus, although R&D funding is making some headway despite galloping inflation, the increase is not very great.

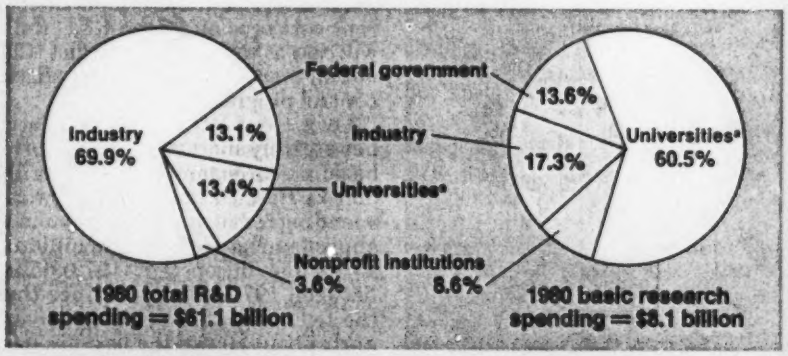
The National Science Foundation anticipates that U.S. funding of R&D will rise from $61.1 billion in 1980 to $69.1 billion in 1981, a gain of 13%. In constant dollars, however, the increase is merely 3%, the lowest real gain since 1975.

Industry is the leading performer of R&D in the U.S. In 1980, companies conducted about 70% of all R&D, as measured by dollars spent.

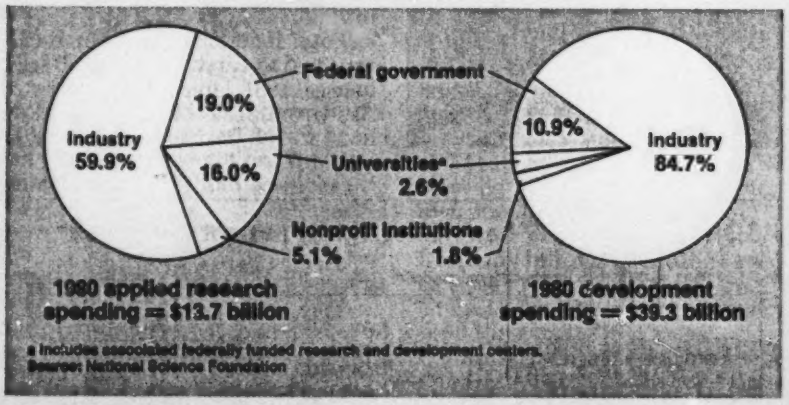
Industry also is the leading performer of applied research (about 60% of the total in 1980) and development (about 85%). On the other hand, universities do about 61% of the nation's basic research.

Of all U.S. spending on R&D in 1980, 13.3% went for basic research, 22.4% for applied research, and 64.3% for development. Although science leaders have spoken frequently of the need to increase the share of R&D spending that goes for basic research, not much has changed in this regard in recent years. In 1978, 12.8% of total R&D spending went for basic research, and in 1979 the figure was 13.4%. □

Industry performs most R&D, with universities handling the bulk of basic research . . .



. . . and industrial laboratories dominate in applied research and especially in development work



a Includes associated federally funded research and development centers.
Source: National Science Foundation

TRENDS IN R&D: Nonfederal outlays have accounted for more than half of total since 1979

% of total outlays	1981[a]	1980[a]	1979[a]	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962
Federal	47%	48%	49%	50%	50%	51%	51%	51%	53%	55%	56%	57%	58%	61%	62%	64%	65%	66%	66%	64%
Defense related	23	23	23	24	25	26	27	28	31	32	32	33	34	35	35	33	33	37	41	48
Space related	7	8	7	7	7	8	7	7	7	8	9	10	11	13	14	19	21	19	14	7
Civilian related	17	18	19	19	18	17	17	16	15	15	15	14	13	13	13	12	11	11	10	10
Nonfederal	53	52	51	50	50	49	49	49	47	45	44	43	42	39	38	36	35	34	34	36

a Estimated. Note: Data may not total 100% because of rounding. Source: National Science Foundation

SOURCES OF R&D FUNDS: Industry now exceeds government as largest source . . .

$ Billions, current	1982[a]	1981[a]	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	Annual change 1980–81	Annual change 1971–81
Federal government	$37.6	$32.7	$29.3	$26.6	$23.9	$21.6	$19.8	$18.1	$16.8	$16.3	$15.8	$14.9	11%	8%
Industry	38.6	33.9	29.5	25.6	22.3	19.7	17.7	15.8	14.9	13.3	11.7	10.8	15	12
Universities and colleges	1.6	1.5	1.4	1.2	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5	7	12
Other nonprofit institutions	1.3	1.1	1.0	0.8	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	9	11
TOTAL	$79.0	$69.1	$61.1	$54.2	$48.0	$42.9	$38.9	$35.2	$32.8	$30.7	$28.4	$26.7	13%	10%

a Estimated. Source: National Science Foundation

. . . as its contribution shows biggest gain in constant dollars

$ Billions, constant (1972)	1982[a]	1981[a]	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	Annual change 1980–81	Annual change 1971–81
Federal government	$17.8	$16.8	$16.6	$16.3	$15.9	$15.5	$15.0	$14.5	$14.8	$15.6	$15.8	$15.6	1%	1%
Industry	18.3	17.4	16.6	15.8	14.9	14.1	13.4	12.6	12.9	12.6	11.7	11.3	5	4
Universities and colleges	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	−3	3
Other nonprofit institutions	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	−1	2
TOTAL	$37.4	$35.5	$34.5	$33.3	$32.0	$30.7	$29.4	$28.2	$28.8	$29.1	$28.4	$27.8	3%	2%

a Estimated. Source: National Science Foundation

PERFORMERS OF R&D: Industry does about 70% of total R&D . . .

$ Billions, current	1982[a]	1981[a]	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	Annual change 1980–81	Annual change 1971–81
Industry	$57.0	$49.2	$42.8	$37.6	$33.2	$29.9	$27.0	$24.2	$22.9	$21.2	$19.6	$18.3	15%	10%
Federal government	10.1	9.0	8.1	7.5	6.9	6.1	5.7	5.3	4.9	4.7	4.5	4.2	11	8
Universities and colleges	6.8	6.3	6.0	5.2	4.6	4.1	3.7	3.4	3.0	2.9	2.6	2.5	5	10
Associated FFRDC's[b]	2.4	2.3	2.2	1.9	1.7	1.4	1.1	1.0	0.9	0.8	0.8	0.7	5	13
Other nonprofit institutions	2.8	2.4	2.2	2.0	1.7	1.5	1.4	1.3	1.2	1.0	1.0	0.9	8	10
TOTAL	$79.0	$69.1	$61.1	$54.2	$48.0	$42.9	$38.9	$35.2	$32.8	$30.7	$28.4	$26.7	13%	10%

a Estimated. b Federally funded research and development centers administered by universities and colleges. Source: National Science Foundation

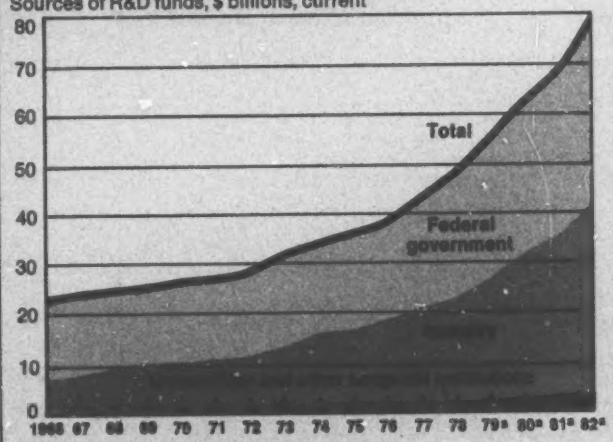
. . . and turns in the only significant gain recently in real dollars

$ Billions, constant (1972)	1982[a]	1981[a]	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	Annual change 1980–81	Annual change 1971–81
Industry	$27.0	$25.2	$24.1	$23.1	$22.1	$21.4	$20.4	$19.3	$19.9	$20.1	$19.6	$19.1	5%	3%
Federal government	4.8	4.6	4.6	4.6	4.6	4.3	4.3	4.3	4.3	4.5	4.5	4.4	1	0
Universities and colleges	3.2	3.2	3.4	3.2	3.1	2.9	2.8	2.8	2.7	2.8	2.6	2.6	−4	2
Associated FFRDC's[b]	1.1	1.2	1.2	1.2	1.1	1.0	0.9	0.8	0.8	0.8	0.8	0.7	−5	6
Other nonprofit institutions	1.3	1.2	1.2	1.2	1.1	1.1	1.0	1.0	1.0	1.0	1.0	0.9	−2	3
TOTAL	$37.4	$35.5	$34.5	$33.3	$32.0	$30.7	$29.5	$28.2	$28.8	$29.1	$28.4	$27.8	3%	2%

a Estimated. b Federally funded research and development centers administered by universities and colleges. Source: National Science Foundation

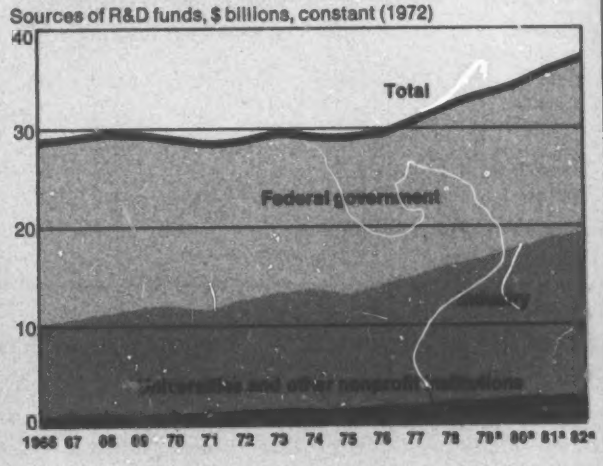
Total spending for R&D has risen steadily over the past 15 years...

Sources of R&D funds, $ billions, current



...although inflation has eroded these increases markedly

Sources of R&D funds, $ billions, constant (1972)



a Estimated. Source: National Science Foundation

CHARACTER OF R&D: Heftiest share of R&D funds goes for development programs, . . .

$ Billions, current	1981a	1980a	1979a	1978	1977	1976	1975	1974	1973	1972	1971	Annual change 1980–81	Annual change 1971–81
Basic research	$ 8.8	$ 8.1	$ 7.2	$ 6.3	$ 5.5	$ 4.9	$ 4.6	$ 4.2	$ 3.9	$ 3.8	$ 3.6	9%	9%
Applied research	15.3	13.7	12.2	10.8	9.8	9.0	7.9	7.2	6.5	6.0	5.8	12	10
Development	45.0	39.3	34.9	30.9	27.7	25.0	22.7	21.4	20.2	18.7	17.2	15	10

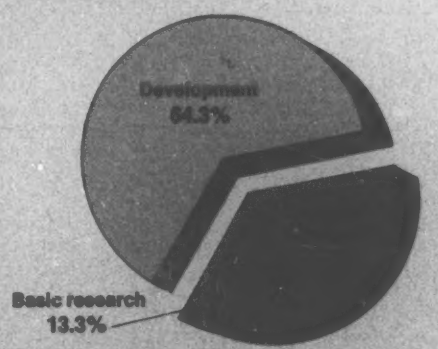
a Estimated. Source: National Science Foundation

. . . which also will show largest increase in spending this year

$ Billions, constant (1972)	1981a	1980a	1979a	1978	1977	1976	1975	1974	1973	1972	1971	Annual change 1980–81	Annual change 1971–81
Basic research	$ 4.5	$ 4.6	$ 4.4	$ 4.2	$ 3.9	$ 3.7	$ 3.7	$ 3.7	$ 3.7	$ 3.8	$ 3.8	−2%	2%
Applied research	7.9	7.7	7.5	7.2	7.0	6.8	6.3	6.3	6.3	6.0	6.0	3	3
Development	23.1	21.2	21.4	20.6	19.8	18.9	18.2	18.7	19.1	18.7	18.0	9	3

a Estimated. Source: National Science Foundation

Most R&D spending in the U.S. goes for development work



1980 total R&D spending = $61.1 billion

Source: National Science Foundation

EMPLOYED SCIENTISTS AND ENGINEERS: Chemists make up 6% of total

Thousands	1979	1978	1974
Physical scientists	212.4	227.4	201.4
Chemists	143.7	150.4	133.5
Physicists/astronomers	51.2	58.5	52.7
Engineers	1268.4	1240.7	1212.6
Chemical	62.0	na	na
Other scientists	992.4	909.1	834.2
TOTAL	2473.2	2377.2	2248.2

na = not available. Source: National Science Foundation

ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS:* Almost 40% deal with biochemistry

% IN EACH GROUP	1980	1979	1978	1977	1976	1975	1974	1973	1972
Biochemistry	39.8%	38.8%	38.3%	37.9%	38.8%	39.4%	36.2%	35.9%	35.6%
Physical and analytical chemistry[a]	28.6	28.9	27.4	27.9	27.5	29.6	29.7	31.0	32.2
Applied chemistry and chemical engineering	18.9	19.4	20.8	19.7	18.8	15.5	18.4	16.7	15.7
Organic chemistry	7.4	7.6	8.0	8.8	8.7	9.0	9.4	10.0	9.5
Macromolecular chemistry	5.3	5.3	5.5	5.7	6.2	6.5	6.3	6.4	7.0
% OF ALL BIOCHEMISTRY ABSTRACTS									
Mammalian biochemistry	16.3%	17.1%	17.2%	17.7%	16.3%	15.3%	16.6%	13.7%	13.0%
Pharmacodynamics	12.0	11.9	12.3	12.0	12.0	12.0	11.1	11.1	12.0
Toxicology	8.3	7.4	7.5	6.2	6.4	6.6	5.6	5.9	5.5
General biochemistry	6.6	7.0	6.5	7.0	7.1	7.5	7.3	7.9	7.4
Enzymes	6.2	6.4	5.7	6.1	6.4	7.4	6.4	5.8	6.6
Others	50.6	50.2	50.8	51.0	51.8	51.2	53.0	55.6	55.5
% OF ALL PHYSICAL AND ANALYTICAL CHEMISTRY ABSTRACTS[a]									
Nuclear chemistry	23.2%	25.1%	20.7%	21.1%	19.7%	20.0%	15.8%	19.0%	18.1%
Spectra	18.2	17.0	17.0	18.1	17.8	17.2	18.2	16.8	17.5
Electric phenomena	11.2	11.4	10.9	10.5	10.5	10.3	11.4	10.8	11.2
Crystallization and crystal structure	8.1	8.2	9.2	8.9	9.7	9.6	10.1	10.2	10.1
General physical chemistry	7.1	6.6	6.6	6.8	7.0	6.8	6.4	7.2	6.9
Analytical chemistry	5.6	5.6	7.2	5.8	6.6	6.1	7.4	6.9	6.8
Others	26.6	25.8	28.4	28.8	28.7	30.0	30.7	29.1	29.4
% OF ALL APPLIED CHEMISTRY AND CHEMICAL ENGINEERING ABSTRACTS									
Metals and alloys	22.0%	23.6%	24.0%	24.2%	27.8%	24.4%	27.9%	24.2%	26.6%
Water, wastes, and pollution	22.5	20.8	20.8	23.2	18.6	15.2	18.2	15.6	14.8
Mineralogical and geological chemistry	15.7	15.8	16.8	13.4	17.6	17.5	17.6	20.2	19.8
Fossil fuels, derivatives, and related products	8.9	7.8	8.2	9.2	6.0	9.8	4.0	8.0	7.3
Unit operations and processes	5.0	6.1	6.4	5.8	4.8	5.3	5.6	7.8	7.0
Others	24.9	25.9	23.8	24.2	25.2	27.8	26.7	24.2	24.5
% OF ALL ORGANIC CHEMISTRY ABSTRACTS									
Physical organic chemistry	38.8%	38.8%	36.8%	41.3%	38.4%	40.8%	37.3%	37.2%	35.6%
Heterocyclic compounds	17.3	16.0	17.5	17.0	17.4	16.4	17.3	17.8	19.5
Organometallic and organometalloidal compounds	8.2	8.5	8.9	8.5	8.7	8.4	8.2	7.6	8.6
Aromatic compounds	7.8	8.2	8.6	8.5	8.0	8.7	9.4	10.0	10.1
Aliphatic compounds	6.0	6.0	6.9	5.9	6.5	6.3	7.1	7.1	5.6
Carbohydrates	5.7	6.0	5.2	4.6	5.1	4.9	5.5	5.6	5.2
Others	16.2	16.5	16.1	14.2	15.9	14.5	15.2	14.5	15.4
% OF ALL MACROMOLECULAR CHEMISTRY ABSTRACTS									
Plastics manufacture and uses	26.1%	27.8%	28.1%	27.5%	26.8%	23.3%	23.1%	24.9%	24.0%
Synthetic high polymers	27.0	26.3	25.6	26.5	26.3	30.6	30.6	27.7	26.5
Cellulose, lignin, paper, and other wood products	10.9	11.1	10.6	10.0	9.1	9.2	9.2	9.8	9.2
Textiles	10.1	10.1	12.1	11.0	11.1	10.2	9.8	11.0	13.3
Coatings, inks, and related products	7.4	8.1	7.5	7.5	7.6	7.3	8.1	8.1	7.7
Elastomers, including natural rubber	8.4	7.6	8.0	8.5	8.6	9.2	10.4	9.2	9.7
Others	8.1	9.0	8.1	9.0	8.5	10.2	8.8	9.3	9.6

a Includes inorganic chemistry. Source: Chemical Abstracts Service

U.S. PATENTS: Growing percentage granted to foreigners in past decade

	1980	1979[a]	1978	1977	1976	1975	1974	1973	1972	1971	1970
U.S.[b]	37,152	30,605	40,979	41,383	44,162	46,603	50,643	51,501	51,515	55,988	47,073
Foreign[c]	24,675	18,248	25,123	23,886	26,074	25,291	25,632	22,638	23,293	22,328	17,354
TOTAL	61,827	48,853	66,102	65,269	70,236	71,894	76,275	74,139	74,808	78,316	64,427
% Foreign	39.9%	37.4%	38.0%	36.6%	37.1%	35.3%	33.6%	30.5%	31.1%	28.5%	26.9%

a Patent figures were low in 1979 because the Patent & Trademark Office was short of funds to print patents it might otherwise have issued. b U.S. patents granted to U.S. residents. c U.S. patents granted to residents of foreign countries. Source: Patent & Trademark Office

Federal agencies to hike R&D outlays 11% in fiscal 1981

Spending is likely to be higher again next year, but several agencies are facing cutbacks

FEDERAL OBLIGATIONS FOR R&D: Defense, energy, and space get most funding

Department or agency	Total R&D ($ millions) 1981[a]	1980[a]	1979	1978	1977
Agriculture	$ 777.5	$ 731.7	$ 663.0	$ 621.3	$ 547.0
Science & Education Administration	598.0	575.4	518.4	483.0	426.2
Commerce	372.6	338.3	309.4	283.7	244.7
National Bureau of Standards	79.1	76.1	67.8	58.3	53.2
Defense	16,804.4	13,787.7	12,506.2	11,553.6	10,963.4
Army	3,363.9	2,951.9	2,768.7	2,548.9	2,441.9
Navy	4,891.3	4,809.6	4,335.0	3,998.4	3,817.4
Air Force	7,059.9	5,021.8	4,525.6	4,262.3	4,031.1
Energy	4,994.8	4,949.7	4,638.8	4,244.8	3,536.2
Health & Human Services	3,907.5	3,776.9	3,504.9	3,207.3[b]	2,787.3[b]
National Institutes of Health	3,272.9	3,161.6	2,953.1	2,580.9	2,243.9
Interior	425.0	425.6	405.8	385.2	296.3
Environmental Protection Agency	444.9	414.8	410.1	384.6	295.5
National Aeronautics & Space Administration	5,397.7	5,113.7	4,411.0	3,875.4	3,703.4
National Science Foundation	994.8	904.3	807.9	748.8	697.0
Tennessee Valley Authority	72.1	59.0	38.4	31.5	26.5
Others	1,500.8	1,376.5	1,282.9	1,076.1	831.8
TOTAL	$35,492.1	$31,878.2	$26,978.4	$26,414.3	$23,929.1

a Estimated. b For Department of Health, Education & Welfare. Note: Fiscal years. Source: National Science Foundation

FEDERAL OBLIGATIONS FOR RESEARCH: Greatest support goes to health research

Department or agency, $ millions	1981[a] Basic research	1981[a] Applied research	1980[a] Basic research	1980[a] Applied research	1979 Basic research	1979 Applied research	1978 Basic research	1978 Applied research	1977 Basic research	1977 Applied research
Agriculture	$ 323.6	$ 418.8	$ 288.0	$ 409.5	$ 256.4	$ 375.5	$ 242.7	$ 351.8	$ 204.5	$ 319.6
Science & Education Administration	272.7	298.2	246.5	301.6	218.6	274.8	207.9	253.2	174.0	234.3
Commerce	32.2	237.5	29.0	215.6	24.8	194.7	23.9	168.9	23.2	153.0
National Bureau of Standards	14.8	47.8	12.5	46.9	8.8	43.0	5.9	42.6	6.9	38.0
Defense	515.4	2444.9	430.3	2004.2	383.3	1788.3	319.1	1622.1	294.8	1746.6
Army	107.8	605.4	73.9	460.1	59.5	402.7	54.5	359.8	58.6	374.9
Navy	194.8	404.3	167.0	329.0	147.7	285.1	130.3	271.7	115.3	262.6
Air Force	125.3	771.8	110.0	698.3	96.8	653.9	95.1	590.6	85.3	750.0
Energy	581.8	843.1	520.3	749.4	463.0	668.8	440.5	661.7	389.5	501.8
Health & Human Services	1788.1	1643.0	1698.6	1583.9	1578.0	1439.7	1292.3[b]	1448.4[b]	757.2[b]	1876.5[b]
National Institutes of Health	1657.1	1198.9	1579.5	1164.3	1483.7	1066.4	1161.1	1051.5	670.5	1317.6
Interior	77.0	289.0	76.1	286.6	72.5	296.9	145.7	164.1	128.9	108.6
Environmental Protection Agency	18.5	266.7	13.5	245.0	10.1	248.9	6.0	248.7	8.3	197.0
National Aeronautics & Space Administration	544.7	1056.2	537.8	1076.8	512.8	938.4	479.7	895.4	413.8	792.3
National Science Foundation	906.3	77.5	820.9	74.5	733.3	68.8	678.0	65.5	624.9	63.4
Tennessee Valley Authority	4.9	23.4	4.3	17.8	4.1	12.4	3.8	9.7	3.5	19.3
Others	109.4	706.3	99.8	631.2	81.0	575.4	67.4	447.5	45.5	369.0
TOTAL	$4901.9	$8006.4	$4566.6	$7294.5	$4087.3	$6575.9	$3669.1	$6051.8	$2694.1	$5947.1

a Estimated. b For Department of Health, Education & Welfare. Note: Fiscal years. Source: National Science Foundation

FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Nearly 20% go to physical sciences

$ Millions for research only	1981[a]	1980[a]	1979	1978	1977	Annual change 1980–81	Annual change 1977–81
Physical sciences	$ 2,263	$ 1,980	$ 1,822	$1683	$1511	14%	11%
Chemistry	534	492	453	416	411	9	7
Physics	1,345	1,141	1,044	965	841	18	12
Life sciences	4,432	4,187	3,850	3430	3019	6	10
Environmental sciences	1,329	1,250	1,103	1050	921	6	10
Mathematics and computer sciences	353	282	257	236	176	25	19
Engineering	3,246	2,963	2,623	2446	2426	10	8
Chemical	157	129	124	153	107	22	10
Metallurgy and materials	319	279	251	295	314	14	0
Other sciences	1,285	1,141	1,018	906	788	13	13
TOTAL	$12,908	$11,803	$10,673	$9751	$8841	9%	10%

a Estimated. Note: Fiscal years. Source: National Science Foundation

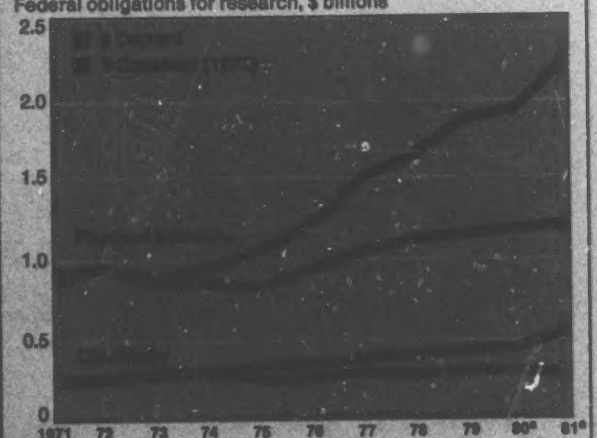
FEDERAL OBLIGATIONS FOR DEVELOPMENT: Defense Department is source for 60%

Department or agency	Development ($ millions) 1981[a]	1980[a]	1979	1978	1977
Agriculture	$ 35.2	$ 34.3	$ 31.1	$ 26.8	$ 22.9
Science & Education Administration	27.1	27.3	24.9	21.8	18.0
Commerce	102.9	93.8	89.9	90.9	68.6
National Bureau of Standards	16.5	16.7	16.0	9.8	8.3
Defense	13,644.1	11,353.2	10,354.6	9,612.4	8,922.0
Army	2,650.7	2,417.8	2,306.5	2,134.6	2,008.5
Navy	4,292.2	4,313.6	3,902.2	3,596.4	3,439.4
Air Force	6,162.8	4,213.5	3,774.9	3,576.6	3,195.8
Energy	3,569.8	3,680.0	3,506.9	3,142.8	2,645.0
Health & Human Services	476.4	494.4	489.2	466.5[b]	353.6[b]
National Institutes of Health	416.8	417.8	423.0	348.3	255.8
Interior	59.0	62.9	66.3	75.5	58.7
Environmental Protection Agency	159.7	156.3	151.1	132.0	90.2
National Aeronautics & Space Administration	3,796.8	3,499.0	2,959.8	2,530.2	2,497.3
National Science Foundation	11.0	9.0	7.9	5.3	8.7
Tennessee Valley Authority	43.8	36.8	21.9	18.0	3.8
Others	685.1	655.4	626.5	563.2	417.3
TOTAL	$22,583.8	$20,075.1	$18,305.2	$16,863.4	$15,087.9

a Estimated. b For Department of Health, Education & Welfare. Note: Fiscal years. Source: National Science Foundation

Federal outlays for chemistry in constant dollars have changed little in recent years

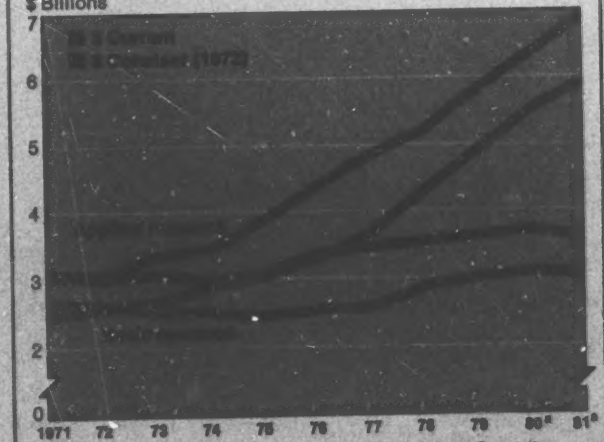
Federal obligations for research, $ billions



a Estimates. Note: Fiscal years. Source: National Science Foundation

Government support of research has increased, but inflation makes inroads

$ Billions



a Estimates. Note: Calendar years. Source: National Science Foundation

OBLIGATIONS FOR PHYSICAL SCIENCE RESEARCH: Chemistry's biggest share is from military

Department or agency	Federal obligations ($ millions) 1981[a] Physical sciences	1981[a] Chemistry	1980[a] Physical sciences	1980[a] Chemistry	1979 Physical sciences	1979 Chemistry	1978 Physical sciences	1978 Chemistry	1977 Physical sciences	1977 Chemistry
Agriculture	$ 58.8	$ 55.0	$ 56.3	$ 52.7	$ 50.6	$ 47.2	$ 52.1	$ 47.8	$ 63.4	$ 53.8
Science & Education Administration	54.3	51.5	52.3	49.6	46.8	44.2	47.1	44.4	58.6	50.9
Commerce	41.8	10.1	38.6	9.6	35.5	8.9	32.5	8.2	27.8	9.5
National Bureau of Standards	34.7	8.7	32.5	8.3	29.8	7.7	27.5	7.1	24.7	7.8
Defense	520.6	119.1	422.4	109.1	385.4	97.6	358.4	71.3	289.3	90.9
Army	128.0	68.8	96.0	56.3	90.2	51.0	84.2	30.1	82.9	62.5
Navy	151.3	25.4	124.7	20.2	106.2	16.2	100.6	17.8	95.3	15.3
Air Force	101.3	24.5	101.8	32.1	120.1	29.6	94.4	22.7	30.9	11.8
Energy	872.5	87.6	745.8	79.8	683.4	72.3	615.8	76.1	552.8	76.3
Health & Human Services	79.3	71.3	76.1	68.4	69.8	62.8	58.3[b]	52.5[b]	54.0[b]	49.3[b]
National Institutes of Health	78.1	70.1	75.0	67.3	69.2	62.1	57.1	51.2	53.1	48.3
Interior	17.2	12.9	16.9	12.8	15.7	11.8	18.9	15.2	13.8	11.2
Geological Survey	7.8	5.7	7.3	5.5	6.6	4.9	13.2	11.1	9.4	7.9
Environmental Protection Agency	79.2	77.5	72.3	71.4	73.2	72.5	70.7	67.8	50.2	46.0
National Aeronautics & Space Administration	311.9	8.4	304.2	6.8	304.8	6.4	264.8	9.3	264.2	11.8
National Science Foundation	260.2	82.3	229.3	73.1	205.8	65.6	195.7	60.3	184.2	57.7
Tennessee Valley Authority	6.7	6.7	5.6	5.6	5.4	5.4	5.4	5.4	4.4	4.4
Others	14.3	3.0	12.9	2.8	11.9	2.6	10.8	1.7	6.5	0.3
TOTAL	$2262.5	$533.9	$1980.4	$491.9	$1821.5	$453.1	$1683.4	$415.6	$1510.6	$411.2

a Estimated. b For Department of Health, Education & Welfare. Note: Fiscal years. Source: National Science Foundation

BASIC RESEARCH: Leading supporters of basic chemistry are NSF and Energy Department

Department or agency	Federal obligations ($ millions) 1981[a] Physical sciences	1981[a] Chemistry	1980[a] Physical sciences	1980[a] Chemistry	1979 Physical sciences	1979 Chemistry	1978 Physical sciences	1978 Chemistry	1977 Physical sciences	1977 Chemistry
Agriculture	$ 29.5	$ 27.7	$ 27.1	$ 25.5	$ 23.8	$ 22.3	$ 25.4	$ 23.6	$ 27.5	$ 23.9
Science & Education Administration	27.7	26.2	25.5	24.1	22.3	21.0	23.2	21.9	25.5	22.6
Commerce	14.2	2.7	12.0	2.4	8.9	1.7	6.6	1.0	8.2	2.8
National Bureau of Standards	13.0	2.6	10.9	2.2	7.9	1.6	5.7	0.9	5.7	1.8
Defense	134.1	33.0	116.0	29.3	89.9	24.5	73.1	20.9	72.2	25.3
Army	19.3	8.4	13.0	5.6	9.7	4.3	9.3	3.7	14.2	9.6
Navy	60.1	15.1	53.9	12.6	43.6	10.1	37.9	8.2	33.1	7.2
Air Force	26.5	10.4	26.6	10.9	24.0	10.0	22.5	9.0	21.2	8.4
Energy	426.8	72.8	388.3	68.1	345.6	57.7	325.4	47.9	293.8	61.7
Health & Human Services	48.2	41.6	44.2	39.7	40.7	36.7	32.9[b]	29.6[b]	35.3[b]	33.6[b]
National Institutes of Health	45.7	41.0	43.5	39.1	40.3	36.3	32.7	29.6	34.4	32.7
Interior	10.2	7.0	9.4	6.6	9.1	6.5	12.9	10.2	9.4	7.4
Geological Survey	3.0	2.0	2.7	1.8	2.6	1.7	8.9	7.7	6.8	5.8
Environmental Protection Agency	2.6	2.6	2.1	2.1	1.8	1.8	1.7	1.3	1.5	1.1
National Aeronautics & Space Administration	298.9	6.7	290.6	5.3	292.5	5.3	243.1	8.9	239.6	10.3
National Science Foundation	250.5	77.0	220.5	68.2	197.1	60.3	189.8	56.7	179.2	54.4
Tennessee Valley Authority	3.3	3.3	2.7	2.7	2.7	2.7	2.4	2.4	2.3	2.3
Others	10.3	1.2	9.8	1.0	9.4	1.3	9.1	1.5	4.8	0.2
TOTAL	$1226.6	$276.5	$1122.7	$248.9	$1021.5	$220.8	$922.4	$204.2	$873.8	$223.0

a Estimated. b For Department of Health, Education & Welfare. Note: Fiscal years. Source: National Science Foundation

APPLIED RESEARCH: Chemical work emphasizes defense and environment

Department or agency	Federal obligations ($ millions) 1981[a] Physical sciences	1981[a] Chemistry	1980[a] Physical sciences	1980[a] Chemistry	1979 Physical sciences	1979 Chemistry	1978 Physical sciences	1978 Chemistry	1977 Physical sciences	1977 Chemistry
Agriculture	$ 29.4	$ 27.2	$ 29.2	$ 27.2	$ 26.9	$ 25.0	$ 26.7	$ 24.3	$ 36.0	$ 29.9
Science & Education Administration	26.6	25.3	26.8	25.4	24.5	23.2	23.8	22.5	33.1	28.4
Commerce	27.8	7.4	26.6	7.2	26.6	7.2	25.9	7.2	19.6	6.7
National Bureau of Standards	21.8	6.1	21.5	6.0	21.9	6.1	21.8	6.2	19.0	6.1
Defense	386.5	85.3	306.3	79.8	295.5	73.1	285.3	50.4	217.2	65.6
Army	108.7	60.4	82.9	50.6	80.6	46.8	74.9	26.3	68.7	53.0
Navy	91.2	10.3	70.8	7.5	62.6	6.2	62.7	9.6	62.1	6.1
Air Force	74.8	14.1	75.3	21.2	96.0	19.6	71.9	13.8	9.7	3.4
Energy	445.7	14.7	357.4	13.7	317.7	14.6	290.5	28.2	258.9	14.6
Health & Human Services	33.0	29.7	31.9	28.6	29.1	26.1	25.4[b]	22.6[b]	18.7[b]	15.6[b]
National Institutes of Health	32.4	29.1	31.5	28.2	28.8	25.9	24.3	21.6	18.7	15.6
Interior	6.9	5.9	7.4	6.2	6.6	5.3	6.0	5.0	4.4	3.8
Geological Survey	4.6	3.7	4.6	3.7	4.0	3.2	4.3	3.4	2.7	2.1
Environmental Protection Agency	76.6	75.0	70.3	69.4	71.4	70.7	69.1	66.4	48.7	45.0
National Aeronautics & Space Administration	13.0	1.7	13.6	1.6	12.3	1.1	21.7	0.3	24.6	1.4
National Science Foundation	9.7	5.4	8.7	4.8	8.7	5.3	5.9	3.6	5.0	3.3
Tennessee Valley Authority	3.4	3.4	2.9	2.9	2.7	2.7	3.0	3.0	2.1	2.1
Others	4.1	1.8	3.4	1.5	2.5	1.2	1.5	0.4	1.5	0.2
TOTAL	$1035.9	$257.5	$857.7	$242.9	$800.0	$232.3	$761.0	$211.4	$636.7	$188.2

a Estimated. b For Department of Health, Education & Welfare. Note: Fiscal years. Source: National Science Foundation

UNIVERSITY RESEARCH: Life sciences get more than half of federal funds

Federal obligations, $ millions	1981[a]	1980[a]	1979	1978	1977	1976	1975	Annual change 1980–81	Annual change 1975–81
Physical sciences	$ 511.6	$ 453.3	$ 402.6	$ 366.2	$ 323.8	$ 281.3	$ 270.6	13%	11%
Chemistry	171.7	155.2	139.3	122.8	117.1	99.1	95.0	11	10
Physics	274.2	237.2	215.5	198.9	163.5	147.2	141.7	16	12
Life sciences	2077.9	1960.1	1797.6	1606.1	1405.2	1233.6	1140.4	6	11
Environmental sciences	332.1	302.0	275.0	225.7	205.7	170.7	147.8	10	14
Mathematics and computer sciences	111.3	95.9	86.7	78.9	69.8	67.0	64.6	16	9
Engineering	350.2	306.4	276.9	247.0	249.3	191.9	188.8	14	11
Chemical	26.3	25.9	22.7	27.0	17.5	16.3	15.9	2	9
Metallurgy and materials	74.5	60.3	51.1	48.6	48.0	48.0	43.5	24	9
Other sciences	346.7	319.9	285.2	252.3	228.4	227.5	185.8	8	11
TOTAL	$3729.8	$3437.6	$3124.0	$2776.2	$2482.2	$2172.0	$1998.0	9%	11%

a Estimated. Note: Fiscal years. Source: National Science Foundation

UNIVERSITY BASIC RESEARCH: Chemistry will get 13% more federal funding this year

Federal obligations, $ millions	1981[a]	1980[a]	1979	1978	1977	1976	1975	Annual change 1980–81	Annual change 1975–81
Physical sciences	$ 408.8	$ 365.6	$ 320.0	$ 298.9	$ 273.8	$ 243.1	$ 234.8	12%	10%
Chemistry	144.4	127.9	112.8	100.9	101.7	88.1	82.6	13	10
Physics	208.8	185.3	164.6	155.8	135.7	125.2	121.8	13	9
Life sciences	1330.4	1238.8	1138.9	925.9	571.1	608.0	455.2	7	20
Environmental sciences	279.7	251.7	228.8	190.2	165.6	127.6	119.1	11	15
Mathematics and computer sciences	88.8	75.8	68.9	63.7	55.7	48.1	42.1	17	13
Engineering	217.9	181.4	157.1	147.1	134.1	109.8	102.8	20	13
Chemical	16.1	14.0	12.6	9.4	9.5	10.2	10.8	15	7
Metallurgy and materials	68.2	53.9	45.9	42.9	41.2	34.9	32.6	27	13
Other sciences	160.4	145.7	124.5	102.3	91.8	78.3	77.7	10	13
TOTAL	$2485.8	$2259.0	$2036.2	$1726.1	$1291.8	$1112.8	$1031.7	10%	18%

a Estimated. Note: Fiscal years. Source: National Science Foundation

Some federal agencies will have higher R&D budgets next year, but others will be cut back

DEPARTMENT OF ENERGY R&D BUDGET: Most programs face severe cuts

$ Millions	1982 Probable Congressional authorization[a]	1982 Reagan Administration request	1981[b]	1980	1979	% change 1981–82[c]
Nuclear fission	$ 928.2	$ 973.4	$ 792.6	$ 951.8	$ 936.0	17%
General science and research	437.2	439.2	378.0	339.9	193.4	16
Fossil energy	422.9	411.1	744.0	732.1	725.4	−43
Magnetic fusion	302.2	310.7	278.4	248.0	215.9	8
Solar energy	265.8	172.3	464.4	451.9	302.7	−43
Basic energy research	265.4	272.4	221.1	214.4	173.0	10
Environmental R&D	210.1	213.1	202.0	201.5	266.3	4
Conservation	127.0	78.0	284.7	397.3	176.1	−49
Electric energy systems and storage	62.5	47.4	112.7	94.0	56.9	−44
Geothermal	38.6	43.6	130.0	116.2	118.1	−70
TOTAL	$3059.7	$2959.2	$3626.8	$3747.1	$3163.8	−16%

a C&EN estimate based on House and Senate action to date. b Estimate. c Based on probable Congressional authorization. Note: Fiscal years ending Sept. 30.

NSF BUDGET: Some programs up, others way down

$ Millions	1982 Probable Congressional authorization[a]	1982 Reagan Administration request	1981[b]	1980	1979	% change 1981–82[c]
Mathematical and physical sciences	$ 292.9	$ 295.4	$ 257.1	$227.0	$208.9	14%
Astronomical, atmospheric, earth, and ocean sciences	252.1	253.2	228.0	218.0	211.6	11
Biological, behavioral, and social sciences	185.0	172.0	183.0	185.7	157.4	1
Engineering	101.6	102.6	83.0	76.6	109.9	22
Antarctic program	69.8	70.1	64.7	55.8	51.1	8
Program development and management	63.2	63.2	60.7	58.2	54.8	4
Science and engineering education	48.0	9.9	70.7	77.2	80.0	−32
Scientific, technological, and international affairs	46.0	37.7	37.0	36.6	23.7	24
Ocean drilling programs	19.0	26.0	22.0	19.4	11.6	−14
Cross-directorate programs	13.8	0	16.1	15.6	16.9	−14
Special foreign currency	3.5	3.5	5.6	4.7	4.0	−37
TOTAL	$1094.9	$1033.6	$1027.9	$974.8	$927.2	6%

a C&EN estimate based on House and Senate action to date. b Estimate. c Based on probable Congressional authorization. Note: Fiscal years ending Sept. 30.

DEFENSE R&D BUDGET: Up substantially overall

$ Millions	1982 Probable Congressional authorization[a]	1982 Reagan Administration request	1981[b]	1980	1979	% change 1981–82[c]
Air Force	$ 8,995.9	$ 9,398.1	$ 7,415.7	$ 5,055.8	$ 4,358.9	21%
Navy	5,917.9	6,086.4	5,155.6	4,572.1	4,464.4	15
Army	3,826.0	3,905.2	3,207.3	2,846.4	2,638.9	19
Defense agencies	[illegible]1.7	1,881.4	1,295.6	1,044.1	892.9	45
Test and evaluation	53.0	53.0	42.1	42.5	27.6	26
TOTAL	$20,674.5	$21,324.1	$17,116.3	$13,560.9	$12,382.7	21%

a C&EN estimate based on Senate and House action to date. b Estimate. c Based on probable Congressional authorization. Note: Fiscal years ending Sept. 30.

NASA R&D BUDGET: One of few that will be higher in fiscal 1982

$ Millions	1982 Probable Congressional authorization[a]	1982 Reagan Administration request	1981[b]	1980	1979	% change 1981-82[c]
Conduct of R&D	$4984.9	$4993.1	$4338.6	$4051.9	$3477.2	15%
Space shuttle	2161.5	2194.0	2003.0	1871.0	1638.3	8
Space flight operations	909.4	910.9	676.2	446.6	299.7	34
Space applications	435.7	372.9	331.6	331.6	295.2	31
Tracking & data acquisition	407.7	415.2	341.1	332.1	299.9	20
Physics and astronomy	341.9	325.4	320.7	336.8	296.4	7
Aeronautical research & technology	290.4	264.8	272.2	308.3	264.1	7
Planetary exploration	215.3	215.3	175.8	219.9	183.4	23
Space research & technology	130.0	125.3	110.7	115.8	107.3	17
Life sciences	46.3	43.5	42.2	43.8	40.1	10
Expendable launch vehicles	31.2	31.2	54.4	31.2	38.7	−43
Technology utilization	12.6	4.6	6.8	12.0	9.1	85
Energy technology	2.0	0	4.0	3.0	5.0	−50
Research & program management	1116.2	1114.3	1071.4	995.0	933.6	4
Construction of facilities	194.4	194.5	115.0	155.1	147.5	−8
TOTAL	$6304.6	$6122.2	$5524.9	$5207.0	$4558.5	12%

a CSEN estimate based on Senate and House action to date. b Estimate. c Based on probable Congressional authorization. Notes: Fiscal years ending Sept 30.

EPA R&D BUDGET: Toxic substances up, most others down

$ Millions	1982 Probable Congressional authorization[a]	1982 Reagan Administration request	1981[b]	1980	1979	% change 1981-82[c]
Energy	$ 72.0	$ 70.1	$104.9	$103.0	$112.8	−31%
Air	64.9	64.4	67.5	69.0	52.0	−4
Water quality	49.5	48.0	62.0	67.0	65.7	−21
Toxic substances	36.0	38.0	35.5	31.0	16.6	1
Drinking water	29.7	29.7	26.3	23.0	17.6	13
Solid hazardous waste	30.3	31.0	29.6	13.0	6.5	2
Pesticides	6.9	6.9	10.6	13.0	12.7	−35
Interdisciplinary	6.5	6.5	6.4	5.0	19.7	1
Radiation	3.0	3.0	3.2	3.0	1.8	−6
TOTAL	$298.8	$267.6	$346.9	$329.0	$307.4	−14%

a CSEN estimate based on House and Senate action to date. b Estimate. c Based on provable Congressional authorization. Notes: Fiscal years ending Sept. 30.

NIH BUDGET: Administration is asking for a modest 5% increase

$ Millions	1982[a]	1981[b]	1980	1978	1979	% change 1981-82[c]
National Institutes	$3472.6	$3307.5	$3182.5	$2934.6	$2553.1	5%
Cancer	1003.8	990.5	999.8	937.1	873.2	1
Heart, lung & blood	559.7	550.4	527.5	510.1	447.9	2
Arthritis, diabetes, digestive & kidney diseases	386.5	369.5	341.2	302.7	259.5	4
General medical sciences	358.0	334.1	312.5	277.3	230.5	7
Neurological, communicative disorders & stroke	278.2	252.8	242.0	212.1	177.4	10
Allergy & infectious diseases	246.2	232.3	215.4	191.9	164.2	6
Child health & human development	233.3	220.9	208.9	197.3	149.4	6
Eye	133.4	118.1	113.0	104.8	85.2	13
Environmental health sciences	111.5	93.7	83.9	80.6	68.6	19
Aging	85.1	75.7	70.0	58.5	57.1	12
Dental research	77.4	69.1	58.3	54.4	51.8	10
Research Resources	192.1	178.8	168.3	159.7	146.3	8
National Library of Medicine	47.7	44.7	44.6	41.5	38.9	7
Office of the Director	23.8	22.5	21.3	36.6	29.9	4
Research facilities	19.3	18.1	30.0	36.3	56.3	7
John E. Fogarty Center	9.5	8.6	8.8	9.4	8.5	11
TOTAL	$3764.5	$3577.2	$3479.7	$3306.3	$2852.6	5%

a Reagan Administration request. b Estimate. c Based on Administration request. Notes: Fiscal years ending Sept. 30.

Industrial R&D maintains uninterrupted growth

Chemical industry spent about $4.6 billion on R&D last year, which represents an increase of 5% after adjustment for the impact of inflation

TOTAL FUNDS FOR INDUSTRIAL R&D: Chemical producers boost their spending 14%

$ Millions	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Chemicals and allied products	$ 4,600	$ 4,035	$ 3,584	$ 3,256	$ 3,017	$ 2,727	$ 2,450	$ 2,116	$ 1,932	$ 1,832	$ 1,773	14%	10%
Industrial chemicals	2,300	2,026	1,835	1,685	1,524	1,391	1,299	1,119	1,031	1,009	1,031	14	8
Drugs	1,670	1,441	1,270	1,154	1,091	981	807	698	607	549	485	16	13
Other chemicals	630	568	479	417	401	354	344	299	294	274	257	11	9
Other industries	38,200	33,918	29,781	26,672	23,980	21,460	20,437	19,133	17,620	16,488	16,294	13	9
TOTAL	$42,800	$37,953	$33,365	$29,928	$26,997	$24,187	$22,887	$21,249	$19,552	$18,320	$18,067	13%	9%

a C&EN estimates. Source: National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Only 3% goes to the chemical industry

$ Millions	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Chemicals and allied products	$ 410	$ 379	$ 366	$ 300	$ 266	$ 236	$ 214	$ 203	$ 189	$ 184	$ 180	8%	9%
Industrial chemicals	390	360	347	284	249	218	194	183	171	159	158	8	9
Drugs and other chemicals	20	19	19	16	17	18	20	20	18	25	22	5	−1
Other industries	13,290	12,081	10,843	10,221	9295	8369	8006	7942	7828	7482	7599	10	6
TOTAL	$13,700	$12,460	$11,209	$10,521	$9561	$8605	$8220	$8145	$8017	$7666	$7779	10%	6%

a C&EN estimates. Source: National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Chemical spending rises in step with all industry

$ Millions	1980[a]	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Chemicals and allied products	$ 4,190	$ 3,656	$ 3,218	$ 2,956	$ 2,751	$ 2,490	$ 2,236	$ 1,913	$ 1,741	$ 1,648	$ 1,593	15%	10%
Industrial chemicals	1,910	1,666	1,488	1,402	1,275	1,173	1,105	936	860	850	873	15	8
Drugs and other chemicals	2,280	1,990	1,730	1,554	1,476	1,317	1,131	977	881	798	720	15	12
Other industries	24,900	21,851	18,938	16,451	14,685	13,092	12,431	11,191	9,794	9,006	8,695	14	11
TOTAL	$29,190	$25,507	$22,156	$19,407	$17,436	$15,582	$14,667	$13,104	$11,535	$10,654	$10,288	14%	11%

a C&EN estimates. Source: National Science Foundation

COMPANY R&D SPENDING: Sizable increases planned by several chemical companies

$ Millions	1981[a]	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971
Air Products	$ 32	$ 30	$ 24	$ 23	$ 24	$ 19	$ 16	$ 11	$ 8	$ 7	$ 7
Allzona	33	28	25	23	20	18	17	16	13	11	10
Allied Corp.	145	105	70	56	51	40	35	31	29	29	31
American Cyanamid	160	142	124	108	96	83	73	64	52	44	43
Celanese	105[b]	94	92	83	77	70	64	58	49	52	51
Diamond Shamrock	60	50	42	36	29	24	20	14	12	12	11
Dow Chemical	400	314	269	232	203	188	167	149	118	105	95
Du Pont	570	485	415	377	367	353	336	344	286	265	259
W. R. Grace	54	45	42	37	32	28	30	32	28	22	21
Hercules	57	53	47	40	37	35	30	30	25	24	22
Monsanto[c]	230	204	161	136	132	114	116	87	82	92	87
Pennwalt[d]	28	26	24	23	21	19	16	14	13	18	17
Rohm & Haas	80	67	54	49	45	43	45	39	32	25	29
Stauffer Chemical	52	44	37	34	33	29	24	20	17	14	14
Union Carbide	188	166	161	156	156	143	120	94	77	70	78
TOTAL	$2194	$1853	$1587	$1409	$1323	$1206	$1109	$1003	$841	$790	$775
ANNUAL CHANGE	18%	17%	13%	7%	10%	9%	11%	19%	6%	2%	−3%

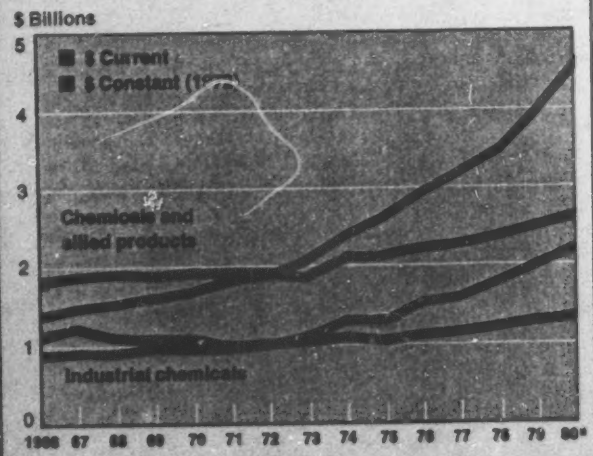
a Planned. b C&EN estimate. c R&D definition narrowed after 1972. d For chemicals only before 1972. Sources: Company data, C&EN estimates

R&D BY U.S. COMPANIES ABROAD: Chemical firms increase spending overseas

$ Millions	1980[a]	1979	1978	1977	1976	1975	1974	Annual change 1979–80	Annual change 1974–80
Chemicals and allied products	$ 500	$ 451	$ 399	$ 332	$ 312	$ 269	$ 208	11%	16%
Industrial and other chemicals	200	182	153	133	108	85	82	10	16
Drugs	300	270	246	199	204	184	126	11	16
Other industries	2600	2217	1811	1526	1332	1172	1082	17	16
TOTAL	$3100	$2668	$2210	$1858	$1644	$1441	$1290	16%	16%

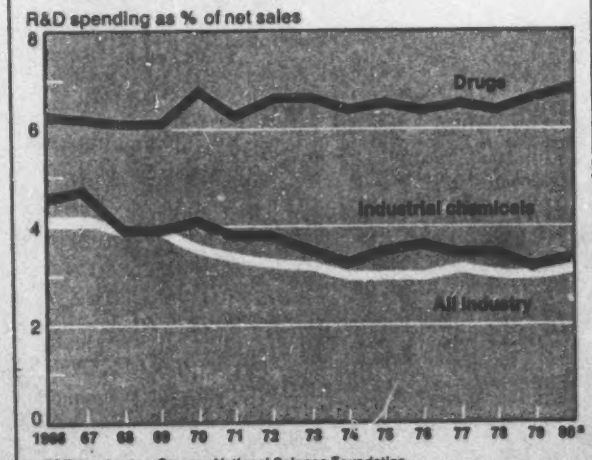
a C&EN estimates. Source: National Science Foundation

Chemical industry's R&D is growing slowly when adjusted for inflation



a C&EN estimates. Source: National Science Foundation

R&D spending increased slightly relative to sales last year



a C&EN estimates. Source: National Science Foundation

APPLIED R&D BY INDUSTRY ON CHEMICALS: Plastics and other polymers are in forefront

$ Millions	1979	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
Industrial chemicals	$675	$620	$548	$494	$445	$363	$371	$383	$398	$390	$382
Plastics, rubber, and fibers	881	747	674	588	589	511	453	496	521	482	466
Agricultural chemicals	292	236	205	176	137	114	108	130	126	104	99
Other chemicals	653	422	426	389	373	323	312	270	267	237	221
Drugs	na	959	883	783	655	586	521	490	447	417	375
TOTAL	na	$2984	$2738	$2410	$2199	$1917	$1765	$1769	$1759	$1630	$1543

na = not available. Note: No data for 1978. Source: National Science Foundation

APPLIED R&D ON CHEMICALS AND DRUGS: Much is done outside the chemical industry

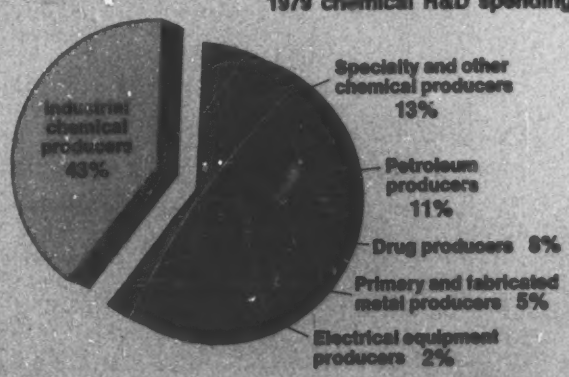
	Product Sold ($ millions)									
	1979		1977		1976		1975		1974	
Industry	Chemicals	Drugs	Chemicals	Drugs	Chemicals	Drugs	Chemicals	Drugs	Chemicals	Drugs
Chemicals and allied products	$1604	$1020	$1327	$903	$1192	$817	$1158	$681	$1059	$598
Industrial chemicals	1086	138	806	101	711	84	807	83	766	66
Drugs	205	840	131	756	130	703	84	567	61	505
Other chemicals	313	42	390	46	351	30	267	31	233	26
Petroleum refining and extraction	283	a	192	7	169	4	170	4	132	3
Rubber products	75	0	44	a	31	a	34	a	31	a
Stone, clay, and glass products	37	0	34	0	31	5	22	0	19	0
Food and kindred products	28	a	26	a	25	5	23	19	23	16
Textiles and apparel	a	0	a	0	a	0	11	a	a	a
Lumber, wood products, and furniture	5	0	10	0	8	0	8	0	7	0
Paper and allied products	36	0	22	a	13	a	16	a	13	a
Primary metals	a	0	55	a	47	0	24	a	21	a
Ferrous metals and products	a	0	14	0	13	0	11	a	10	a
Nonferrous metals and products	a	0	41	a	34	0	12	0	11	0
Fabricated metal products	65	a	47	3	42	4	20	6	21	2
Machinery	26	0	24	a	15	a	26	a	26	0
Electrical equipment and communication products	62	a	49	4	56	6	50	a	46	a
Motor vehicles and motor vehicle equipment	68	0	48	0	42	0	a	0	a	0
Other transportation equipment	19	0	15	0	a	0	a	0	a	0
Aircraft and missiles	25	0	15	0	27	0	35	a	28	a
Professional and scientific instruments	65	54	43	35	37	30	31	42	32	38
Other manufacturing industries	26	0	12	0	10	0	11	0	12	0
Nonmanufacturing industries	a	a	58	a	62	a	24	a	16	a
TOTAL	$2559	$1089	$2024	$959	$1837	$877	$1703	$760	$1510	$658

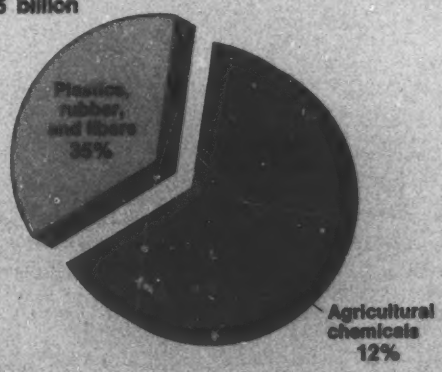
a Not separately available but included in total. Note: No data for 1978. Source: National Science Foundation

Makers of industrial chemicals do the largest amount of chemical R&D ...

...and more than a third of chemical R&D deals with synthetic materials

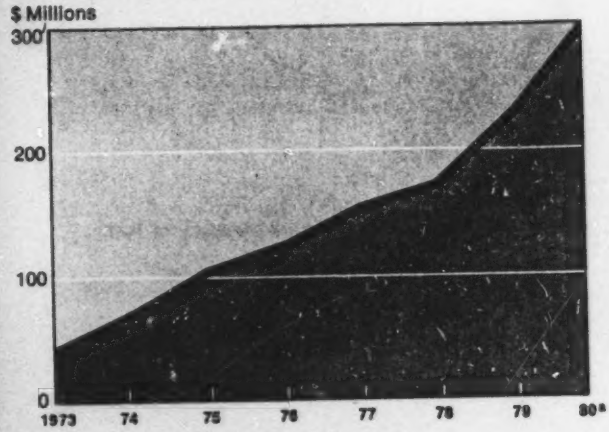
1979 chemical R&D spending[a] = $2.5 billion



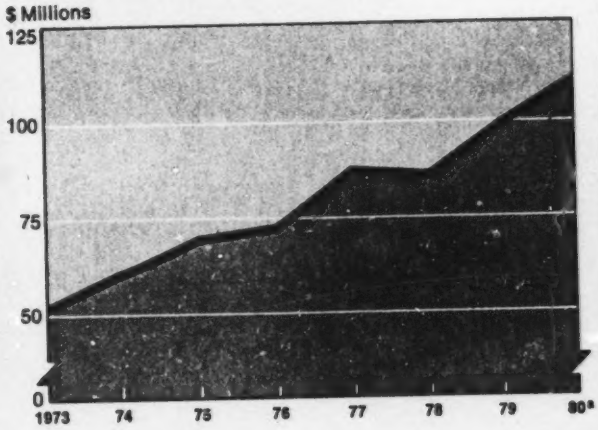


a Excludes basic research and research on drugs. Source: National Science Foundation

Chemical industry's outlays for energy R&D are rising sharply...



...while spending on pollution control R&D grows less rapidly



a C&EN estimates. Source: National Science Foundation

DRUG R&D: Spending by U.S. firms doubled between 1974 and 1980

R&D expenditures for ethical drugs,[a] $ millions	1980[b]	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Company spending on human-use drugs	$1774.6	$1522.9	$1311.2	$1181.8	$1067.8	$ 973.5	$858.5	$752.5	$666.8	$628.8	$565.8	17%	12%
In U.S.	1437.4	1243.1	1089.2	984.1	902.2	828.6	726.0	643.8	600.7	576.5	518.6	16	11
In foreign countries	337.2	279.8	222.0	197.7	164.9	144.9	132.5	108.7	66.1	52.3	46.9	21	22
Company spending on veterinary-use drugs	110.2	96.3	85.5	84.3	86.8	79.0	73.7	61.9	52.5	47.9	45.1	14	9
In U.S.	86.4	76.7	69.9	68.9	71.4	65.9	58.5	53.7	[illegible]	43.1	40.0	13	8
In foreign countries	23.8	19.6	15.9	15.4	15.4	13.1	15.2	8.2	[illegible]	4.8	5.1	21	19
Government grants and contracts	6.9	7.6	7.0	10.0	9.1	9.0	8.6	10.6	8.8	7.1	7.6	−9	−1
TOTAL	$1891.7	$1626.8	$1404.0	$1276.1	$1163.7	$1061.5	$940.8	$881.3	$728.1	$683.8	$618.5	16%	12%

a In the U.S. and abroad for U.S. drug companies and in the U.S. only for U.S.-based subsidiaries of foreign companies. b Budgeted. Source: Pharmaceutical Manufacturers Association

FUNCTION OF DRUG R&D: Clinical studies, screening, and testing take 40% of outlays

R&D function	% of total drug R&D spending[a] 1979	1978	1977	1976
Clinical evaluation	22.1%	21.3%	22.5%	23.4%
Biological screening and pharmacological testing	18.2	18.8	18.7	19.5
Synthesis and extraction	15.6	16.3	17.2	16.6
Toxicology and safety testing	9.6	10.0	9.2	8.9
Dosage formulation and stability testing	9.2	10.1	9.7	9.1
Process development and quality control	8.8	9.2	8.8	9.5
Regulatory preparation and submission	3.6	3.6	3.3	3.3
Bioavailability studies	2.1	2.2	2.3	2.2
Other	10.8	8.5	8.3	7.5

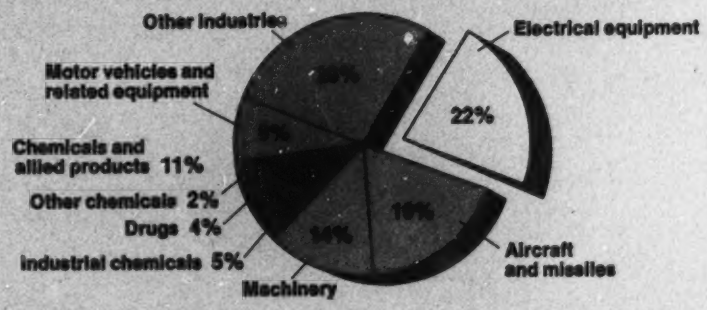
a In U.S. only. Source: Pharmaceutical Manufacturers Association

ALLOCATION OF DRUG R&D: Cardiovasculars are getting more attention

Product class	% of total R&D spending[a] 1979	1978	1977	1976
Anti-infectives	18.7%	18.3%	19.2%	19.5%
Cardiovasculars	18.6	17.3	15.2	13.2
Central nervous system and sense organs	16.3	16.9	17.0	16.2
Neoplasms, endocrine system, and metabolic diseases	15.3	16.1	15.7	14.7
Gastrointestinal and genitourinary system	6.3	6.7	6.0	5.8
Respiratory	4.0	4.4	4.0	4.1
Dermatologicals	2.9	2.8	3.2	2.8
Biologicals	2.5	3.0	3.1	3.1
Vitamins	2.5	2.2	2.5	1.5
Diagnostic (in vivo)	0.5	0.6	0.8	1.2
Other human preparations	6.7	5.6	6.3	10.5
Veterinary preparations	5.3	5.7	6.6	7.2
Veterinary biologicals	0.4	0.4	0.4	0.2

a In U.S. only. Source: Pharmaceutical Manufacturers Association

More R&D scientists and engineers work for electrical equipment producers than any other major industry



1980 total industrial R&D scientists and engineers[a] = 451,700

a Full-time equivalent. Source: National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: Ratio quite high in drug industry

	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
Chemicals and allied products	42	42	42	40	41	40	39	39	41	39	35	35
Industrial chemicals	38	38	38	36	38	37	36	34	35	35	32	32
Drugs	62	64	62	64	59	57	57	60	65	65	48	48
Other chemicals	29	26	28	28	29	30	29	31	31	30	31	30
TOTAL INDUSTRY	28	28	27	27	26	25	24	24	26	26	26	26

Source: National Science Foundation

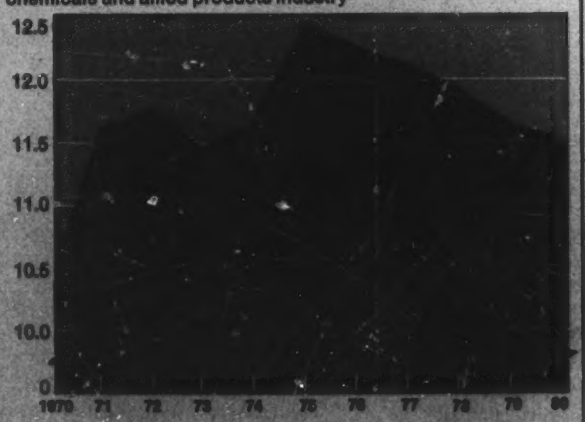
COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: Nearly doubled in a decade

$ Thousands	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969
Chemicals and allied products	$79.5	$73.9	$69.1	$66.5	$60.9	$56.3	$51.1	$47.1	$43.7	$42.8	$41.4
Industrial chemicals	90.5	85.2	80.0	74.7	67.5	63.5	58.6	54.0	49.2	47.5	46.0
Drugs	72.1	65.8	65.0	63.4	60.9	54.3	51.5	46.5	43.2	40.1	40.4
Other chemicals	67.6	63.0	54.2	50.8	43.2	45.3	34.0	33.4	35.5	33.4	29.1
TOTAL INDUSTRY	$86.7	$78.8	$76.1	$72.2	$66.5	$63.3	$59.2	$55.3	$51.1	$48.1	$47.5

Source: National Science Foundation

Share of scientists and engineers working in the chemical industry has been declining

% of industrial R&D scientists and engineers[a] in the chemicals and allied products industry



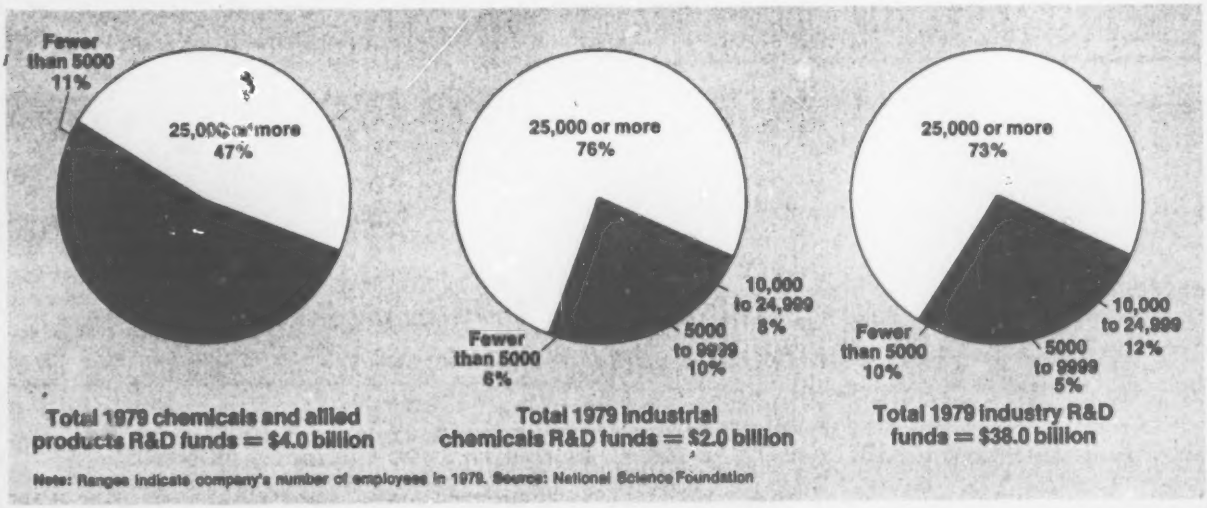
a Full-time equivalent. Source: National Science Foundation

CHEMISTS IN INDUSTRY: Chemical producers employ nearly a third of the total

	% of industrial chemists			
Industry	All chemists	B.S.	M.S.	Ph.D.
Chemical	31%	28%	29%	36%
Pharmaceutical	17	16	19	17
Petroleum	7	5	6	6
Coatings	6	9	6	4
Food	4	5	4	3
Metals and minerals	3	4	4	2
Rubber	3	4	3	2
Paper	2	1	1	2
Other manufacturing	20	20	20	20
Nonmanufacturing	7	8	8	7

Source: 1981 ACS survey

Firms with largest number of employees spend most money on R&D



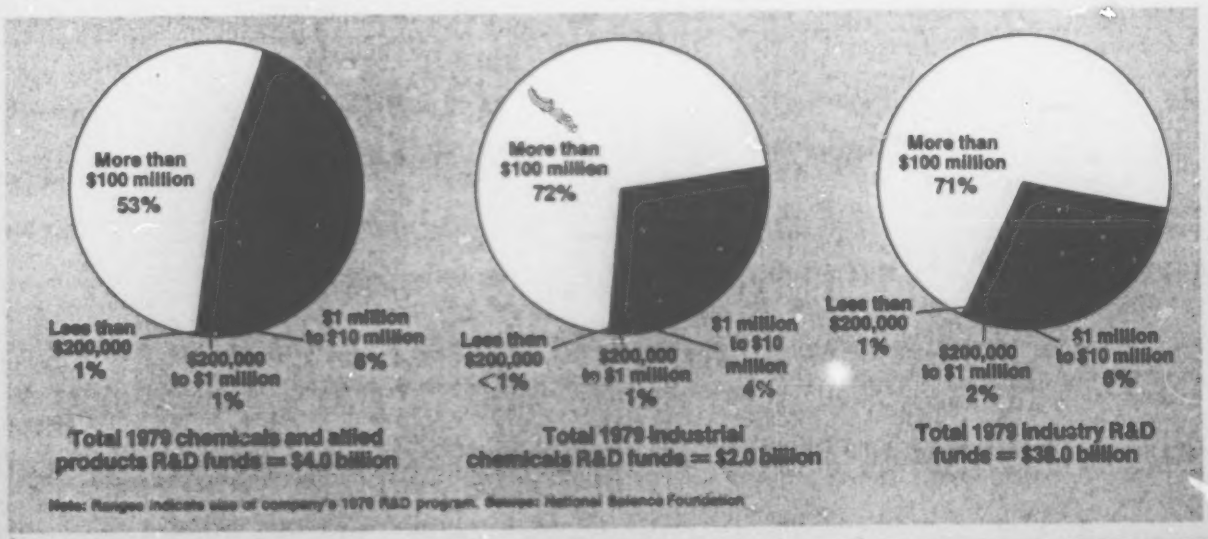
Note: Ranges indicate company's number of employees in 1979. Source: National Science Foundation

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Employment rises 5% in chemical industry

Thousands[a]	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
Chemicals and allied products	51.8	49.1	47.9	46.4	44.4	45.2	41.8	40.9	41.0	42.7	40.1
Industrial chemicals	23.0	21.6	21.5	20.6	20.1	21.1	19.1	19.1	19.1	21.8	21.5
Drugs	20.0	19.7	18.9	17.8	16.6	15.6	14.0	13.0	13.1	12.3	11.8
Other chemicals	8.8	7.8	7.4	8.0	7.8	8.5	8.7	8.8	8.8	8.6	6.8
Other industries	399.9	374.4	355.8	336.4	320.0	318.1	318.2	316.8	309.2	324.3	344.1
TOTAL	451.7	423.5	403.7	382.8	364.4	363.3	360.0	357.7	350.2	367.0	384.2

a Full-time equivalent. Source: National Science Foundation

Most R&D is done by companies with R&D budgets above $10 million on these activities



Note: Ranges indicate size of company's 1979 R&D program. Source: National Science Foundation

Federal sources fund two thirds of academic R&D

Spending for chemical R&D in U.S. universities increased 13% in 1980, faster than in the two previous years but still lagging growth in total outlays

CHARACTER OF UNIVERSITY R&D SPENDING: More than three quarters is for basic work

$ Millions	1980[a]	1979	1978[b]	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Basic research	$4065	$3552	$3165	$2795	$2548	$2410	$2154	$2053	$2022	$1914	$1796	14%	9%
Applied research	1575	1368	1213	1068	1015	851	736	713	524	474	427	15	15
Development	310	263	236	200	164	148	133	118	84	112	112	18	11
TOTAL	$5950	$5183	$4614	$4063	$3727	$3409	$3023	$2884	$2630	$2500	$2335	15%	10%

a Estimates. b Estimated, based on data from Ph.D.-granting institutions only. Note: Data for institutional fiscal years. Source: National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: Biggest source is growing most slowly

$ Millions	1980[a]	1979	1978[b]	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Federal government	$3900	$3432	$3057	$2729	$2512	$2288	$2032	$1985	$1795	$1724	$1647	14%	9%
State and local governments	540	467	414	373	363	332	307	295	270	255	219	16	9
Industry	225	194	170	139	123	113	96	84	74	70	61	16	14
Institutional funds	845	716	615	508	445	418	370	318	305	274	243	18	13
Other sources	440	374	359	315	285	259	218	202	187	177	165	18	10
TOTAL	$5950	$5183	$4614	$4063	$3727	$3409	$3023	$2884	$2630	$2500	$2335	15%	10%

a Estimates. b Estimated, based on data from Ph.D.-granting institutions only. Note: Data for institutional fiscal years. Source: National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: Chemistry takes third of physical science funds

$ Millions	1980[a]	1979	1978[b]	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Physical sciences	$ 630	$ 559.6	$ 485.3	$ 427.3	$ 379.4	$ 350.3	$ 333.5	$ 328.3	$ 324.2	na	$ 307.3	13%	7%
Chemistry	230	204.1	182.4	163.6	140.2	120.7	115.6	113.7	108.1	na	102.0	13	8
Physics	310	275.7	234.7	201.3	183.1	173.5	169.2	167.0	159.1	na	161.9	12	7
Engineering	830	715.5	601.1	498.5	431.7	381.0	346.9	333.1	341.4	na	318.8	16	10
Total R&D spending	5950	5182.7	4614.1	4063.2	3727.3	3408.6	3022.6	2884.0	2630.4	2500	2334.9	15	10

a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. Note: Data for institutional fiscal years. na = not available. Source: National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Not quite 5% for chemistry

$ Millions	1980[a]	1979	1978[b]	1977	1976	1975	1974	1973	1972	1971	1970	Annual change 1979–80	Annual change 1970–80
Physical sciences	$ 500	$ 449.0	$ 392.3	$ 342.7	$ 305.4	$ 285.0	$ 270.2	$ 268.4	$ 261.0	na	$ 257.8	11%	7%
Chemistry	175	154.0	138.0	125.4	107.9	92.7	88.7	86.6	82.6	na	78.9	14	8
Physics	260	236.9	199.2	171.9	158.1	149.9	146.5	145.4	136.3	na	144.3	10	6
Engineering	540	474.9	407.5	336.7	290.5	259.4	239.3	238.1	252.9	na	245.9	14	8
Total R&D spending	3900	3431.5	3066.9	2729.2	2511.6	2287.8	2032.2	1985.4	1795.0	1724	1647.5	14	9

a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. Note: Data for institutional fiscal years. na = not available. Source: National Science Foundation

TOP 12 UNIVERSITIES IN R&D SPENDING: Biggest spender on science is MIT

$ Millions, fiscal 1979	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math and computer sciences	Other sciences[b]	Total
Massachusetts Institute of Technology	$38.5	$5.3	$59.1	$ 8.5	$18.7	$7.9	$ 8.8	$141.6
U of Wisconsin, Madison	13.3	5.4	9.9	11.9	64.3	4.3	18.6	122.2
U of California, San Diego	17.1	4.2	1.5	53.3	33.5	0.8	1.6	107.7
U of Michigan	4.9	1.4	19.8	12.2	42.9	2.6	24.6	107.0
U of Minnesota	5.1	2.2	8.7	2.6	79.2	1.3	9.1	106.1
Stanford	18.4	4.2	25.2	2.8	43.6	7.7	4.0	101.7
Cornell	20.7	3.4	13.2	2.9	54.0	1.5	8.0	100.3
U of Washington	4.5	0.9	5.4	13.0	61.8	1.3	12.9	99.0
Harvard[c]	13.1	4.3	2.6	2.3	59.5	1.5	9.9	89.0
Columbia, main division	10.6	3.5	5.4	13.6	47.0	0.5	5.8	82.8
U of Pennsylvania	7.7	2.2	4.6	0.9	51.4	2.1	15.3	82.0
U of Illinois, Urbana	9.5	4.0	19.0	7.2	22.8	4.1	13.4	76.0

a Included in physical sciences. b Includes social sciences and psychology. c Estimated. Source: National Science Foundation

TOP 12 UNIVERSITY R&D CENTERS:[a] Most R&D dollars go to physical sciences

$ Millions, fiscal 1979	Physical sciences	Engineering	Environmental sciences	Life sciences	Total[b]
Los Alamos National Lab	$163.4	$129.3	$20.6	$14.4	$330.0
Jet Propulsion Lab	62.4	148.3	14.4	4.9	327.7
Lawrence Livermore National Lab	240.7	46.5	15.6	5.2	323.6
Argonne National Lab	82.0	120.0	38.0	13.7	256.4
Lawrence Berkeley Lab	69.1	15.8	12.8	17.0	119.7
Brookhaven National Lab	69.2	19.7	8.0	14.9	119.2
Lincoln Lab	22.5	76.5	0	0	109.6
Plasma Physics Lab	94.0	0	0	0	94.0
Stanford Linear Accelerator Center	80.7	0	0	0	80.7
Fermi National Accelerator Lab	74.3	0	0	0	74.3
National Center for Atmospheric Research	4.9	0	31.0	0	35.9
Ames Lab	9.9	5.0	0	0	15.1

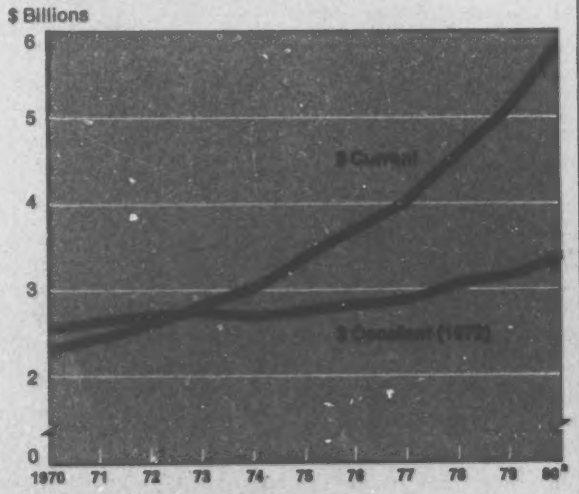
a Data for university-administered federally funded research and development centers. b Includes sciences not listed separately. Source: National Science Foundation

ACADEMIC SCIENTISTS AND ENGINEERS: Chemists account for 5% of total

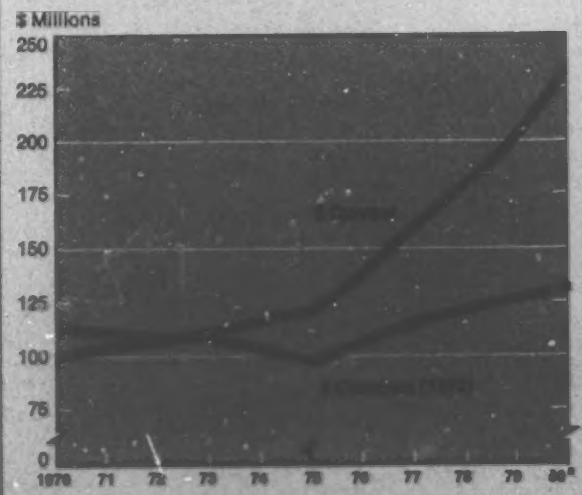
Thousands of scientists and engineers[a]	1980	1978	1977	1976	1975	1974	1973
TOTAL							
Physical scientists	33.7	32.8	32.1	31.4	30.8	30.6	30.2
Chemists	17.7	17.7	17.1	16.6	16.2	16.1	15.3
Physicists	13.1	12.8	12.5	12.2	12.3	12.1	12.2
Engineers	33.8	31.0	30.1	28.5	27.9	27.2	27.5
Chemical	2.4	2.0	1.9	1.9	1.9	1.7	1.6
Other scientists	257.4	243.8	235.6	228.3	220.2	210.7	207.1
TOTAL	324.8	307.6	297.8	288.2	278.9	268.5	264.2
FULL-TIME ONLY							
Physical scientists	28.1	27.9	27.5	27.1	26.7	26.8	26.7
Chemists	14.4	14.7	14.5	14.1	13.8	14.1	13.4
Physicists	11.4	11.3	11.1	10.8	10.9	10.9	11.1
Engineers	26.5	24.7	24.1	22.8	22.6	22.8	23.5
Chemical	1.9	1.7	1.7	1.6	1.6	1.5	1.5
Other scientists	201.0	189.5	184.5	179.8	174.1	168.8	168.3
TOTAL	255.7	242.1	236.2	229.6	223.3	218.4	218.4

a In January. Note: Data not available for 1979. Source: National Science Foundation

Inflation has wiped out much of the rise in total outlays for academic R&D...

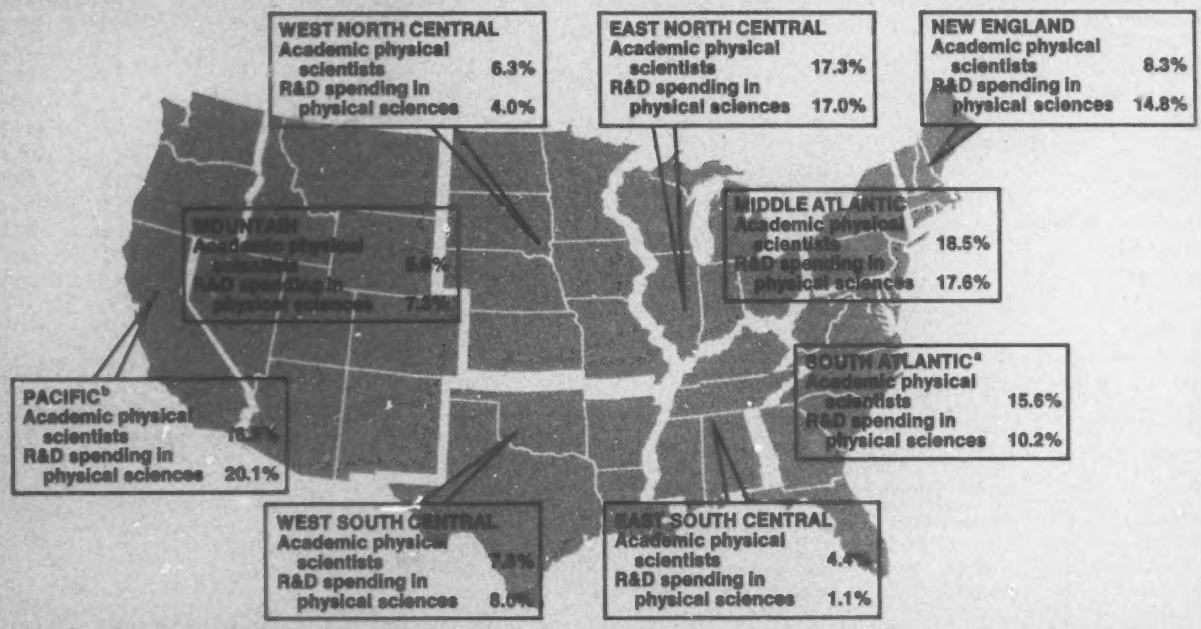


...as well as that in the share being spent for work in chemistry



a Estimated. Note: Data for institutions' fiscal years.
Source: National Science Foundation

Middle Atlantic schools employ the most physical scientists but those along the Pacific lead in outlays for physical science R&D



Key to map: Using Middle Atlantic as an example, 18.5% of all academic employees working in the physical sciences are at universities and colleges in this geographical area and 17.6% of all R&D expenditures in the physical sciences are by universities and colleges in this area. a Includes Puerto Rico. b Includes Alaska and Hawaii. **Note:** Data are based on 33,664 physical scientists employed at colleges and universities as of January 1980 and R&D expenditures of $559.6 million in the physical sciences during the institutions' 1979 fiscal year. **Source:** National Science Foundation

CHEMICAL DEGREES: B.S.'s increase, but chemistry Ph.D.'s continue to decline

Academic year	Degrees awarded in chemistry[a]			Degrees awarded in chemical engineering		
	Bachelors	Masters	Ph.D.'s	Bachelors	Masters	Ph.D.'s
1969–69	11,807	2070	1941	3557	1136	409
1969–70	11,617	2146	2208	3720	1045	438
1970–71	11,183	2284	2160	3615	1100	406
1971–72	10,721	2259	1971	3663	1154	394
1972–73	10,226	2230	1882	3636	1051	397
1973–74	10,525	2138	1828	3454	1045	400
1974–75	10,649	2006	1824	3142	990	346
1975–76	11,107	1796	1623	3203	1031	308
1976–77	11,322	1775	1571	3581	1086	291
1977–78	11,474	1892	1525	4615	1237	259
1978–79	11,643	1765	1518	5655	1149	304

a Does not include biochemistry and geochemistry. **Source:** Department of Education's National Center for Education Statistics

GRADUATE SCIENCE STUDENTS: 6% are studying chemistry or biochemistry

Thousands	1979	1978	1977	1976	1975	1974
TOTAL						
Physical sciences	25.3	25.0	25.3	25.3	24.8	24.7
Chemistry	14.8	14.8	14.7	14.5	14.1	13.8
Physics	9.6	9.5	9.8	9.9	9.9	10.2
Engineering	68.6	65.6	66.2	64.6	65.1	57.2
Chemical	5.6	5.4	5.3	5.2	5.0	4.7
Metallurgical and materials	2.7	2.5	2.5	2.4	2.4	2.3
Petroleum	0.5	0.5	0.4	0.4	0.3	0.3
Biological sciences	41.4	42.2	42.7	41.3	40.8	37.7
Biochemistry	3.8	3.9	3.8	3.7	3.7	3.7
Other sciences[a]	186.5	177.8	175.5	169.2	165.1	147.4
TOTAL	321.8	310.4	309.6	300.4	295.6	267.0
FULL-TIME ONLY						
Physical sciences	21.9	21.7	21.9	21.8	21.4	21.4
Chemistry	12.8	12.6	12.6	12.4	12.0	11.7
Physics	8.5	8.4	8.8	8.8	8.8	9.0
Engineering	39.3	37.0	36.8	36.4	37.1	33.7
Chemical	4.4	4.1	4.0	3.7	3.6	3.3
Metallurgical and materials	2.2	2.0	2.0	1.9	1.8	1.7
Petroleum	0.4	0.4	0.3	0.4	0.3	0.3
Biological sciences	34.9	35.1	35.5	34.8	34.3	32.0
Biochemistry	3.5	3.6	3.5	3.4	3.4	3.4
Other sciences[a]	128.0	123.1	124.2	121.7	119.0	108.7
TOTAL	224.1	218.8	218.4	214.7	210.8	195.9

a Includes environmental, mathematical, health, agricultural, and social sciences and psychology. **Note:** Data for Ph.D.-granting institutions only. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: Wisconsin gains top spot

$ Thousands	Total spending 1979	1978	1977	1976	Federally financed spending 1979	1978	1977	1976
1 U of Wisconsin, Madison	$ 5,450	$ 5,149	$ 5,136	$ 4,702	$ 2,865	$ 2,933	$ 2,880	$ 2,743
2 Massachusetts Inst. of Technology	5,324	6,242	4,735	4,298	5,021	5,837	4,351	3,887
3 California Inst. of Technology	5,297	4,108	5,143	3,860	4,813	3,712	4,322	3,244
4 Harvard U	4,283[a]	3,905[a]	2,958	3,187	3,241	3,396	2,566	2,916
5 U of California, San Diego	4,225	3,611	3,344	3,176	3,913	3,293	3,064	2,922
6 Stanford U	4,159	3,549[a]	2,659	2,238	3,775	3,266	2,581	2,197
7 U of Illinois, Urbana	3,963	3,211	2,498	2,068	2,696	2,426	2,045	1,832
8 U of California, Berkeley	3,717	3,046	3,090	2,948	3,485	2,758	2,742	2,629
9 Texas A&M U	3,715	3,261	3,894	4,132	2,361	2,243	2,205	2,464
10 Georgia Inst. of Technology	3,577	2,784	2,013	1,590	2,110	1,551	1,075	803
Total, first 10 institutions	43,710	38,866	35,410	32,199	34,280	31,415	27,831	25,637
11 U of California, Los Angeles	3,573	3,236	2,563	2,355	3,379	3,052	2,408	2,265
12 Columbia U, main division	3,531	3,321	2,975	2,562	3,202	2,854	2,747	2,186
13 Purdue U	3,438	2,857	2,545	2,171	3,087	2,500	2,170	1,883
14 U of Chicago	3,418[a]	3,113[a]	2,789	2,473	3,039	2,803	2,684	2,348
15 Cornell U	3,414	3,423	3,048	2,702	3,087	3,137	2,888	2,547
16 U of Texas, Austin	3,373	3,057	2,361	1,954	2,282	1,931	1,286	918
17 U of Notre Dame	2,746	2,475	2,560	1,992	2,618	2,389	2,461	1,873
18 U of Massachusetts, Amherst	2,621	2,038	1,922	1,619	1,921	1,633	1,308	1,131
19 Indiana U, Bloomington	2,611	2,199	1,601	1,535	2,301	1,953	1,481	1,357
20 U of Colorado	2,544	899	992	1,401	1,942	688	902	1,146
Total, first 20 institutions	74,979	65,484	58,766	52,963	61,138	54,355	49,166	43,291
21 U of Rochester	2,536	2,100	1,987	1,537	2,056	1,695	1,519	1,221
22 Florida State U	2,478	1,490[b]	1,470	1,475	1,160	777[b]	727[a]	788[a]
23 Pennsylvania State U	2,303	1,904	1,452	1,324	1,969	1,590	1,309	1,150
24 U of Utah	2,290	2,754	7,149	1,868	1,949	1,903	5,636	1,633
25 Princeton U	2,242	1,660	1,508	1,628	1,621	1,271	1,113	1,068
26 U of Pennsylvania	2,211	1,761	973	1,037	1,840	1,356	762	785
27 U of Southern California	2,181	1,676	764	719	1,731	1,381	722	664
28 U of Minnesota	2,162	1,803	1,667	1,443	1,624	1,415	1,279	1,288
29 Yale U	2,107	1,444	1,532	1,346	1,750	1,379	1,455	1,329
30 U of Houston, central campus	2,091	1,171[b]	1,025	1,353	659	607[b]	537	709
Total, first 30 institutions	97,580	83,247	78,293	66,693	77,517	67,735	63,225	53,926
31 Ohio State U	2,039	1,740	2,015	1,687	1,743	1,493	1,738	1,610
32 Wayne State U	2,022	2,740	1,280	1,028	1,555	1,926	1,172	950
33 U of Florida	1,968	1,265	769	631	1,339	1,077	686	575
34 Carnegie-Mellon U	1,967	3,828	4,425	4,231	1,403	1,542	1,079	1,552
35 U of Maryland, College Park	1,907	1,975	1,299	1,568	1,628	1,690	959	1,125
36 Northwestern U	1,851	1,854	1,250	1,231	1,671	1,681	1,068	1,043
37 State U of New York, Stony Brook	1,801	1,637	1,201	1,009	1,554	1,281	1,050	907
38 Colorado State U	1,774	1,398	1,100	881	1,579	1,193	853	766
39 U of Nebraska, Lincoln	1,745	1,040	391	1,026	983	769	347	411
40 U of Pittsburgh	1,728	1,709	1,542	1,129	1,416	1,201	1,328	1,037
Total, first 40 institutions	118,372	102,433	93,655	81,114	92,388	81,588	73,505	63,902
41 U of North Carolina, Chapel Hill	1,685	1,413	1,471	1,422	1,686	1,398	1,448	1,386
42 Michigan State U	1,491	1,262	1,266	1,221	1,045	878	1,063	842
43 Case Western Reserve U	1,413	1,190	1,199	1,250	1,145	940	973	979
44 U of Michigan	1,406	1,171	851	1,247	1,229	982	604	841
45 SUNY College of Env. Sci. & Forestry	1,404	1,364	832	802	533	524	601	481
46 Iowa State U of Science & Tech.	1,288	1,434	736	640	733	589	269	184
47 Virginia Polytechnic Inst. & State U	1,281	1,134[a]	987	553	875	714[a]	674	415
48 U of California, Irvine	1,277	1,435	1,378	1,119	1,243	1,372	1,297	1,082
49 U of Arizona	1,269	1,390	1,512	1,381	860	881	1,145	1,017
50 U of California, San Francisco	1,235	1,110	850	98	1,201	976	792	93[a]
TOTAL, FIRST 50 INSTITUTIONS	$130,121	$115,336	$104,735	$90,827	$102,918	$90,842	$82,371	$71,292
NATIONAL TOTAL	$204,062	$182,428	$163,628	$140,153	$154,031	$137,959	$125,389	$107,871

a Estimate. b Imputed. Note: Data for institutional fiscal years. Source: National Science Foundation

NOTE

ONLY THE FOLLOWING PAGES OF THIS

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Cover 1, p. 1, 8-11.

Chemical & Engineering NEWS
August 3, 1981

Herbicides: new chemicals to combat weeds Page 11

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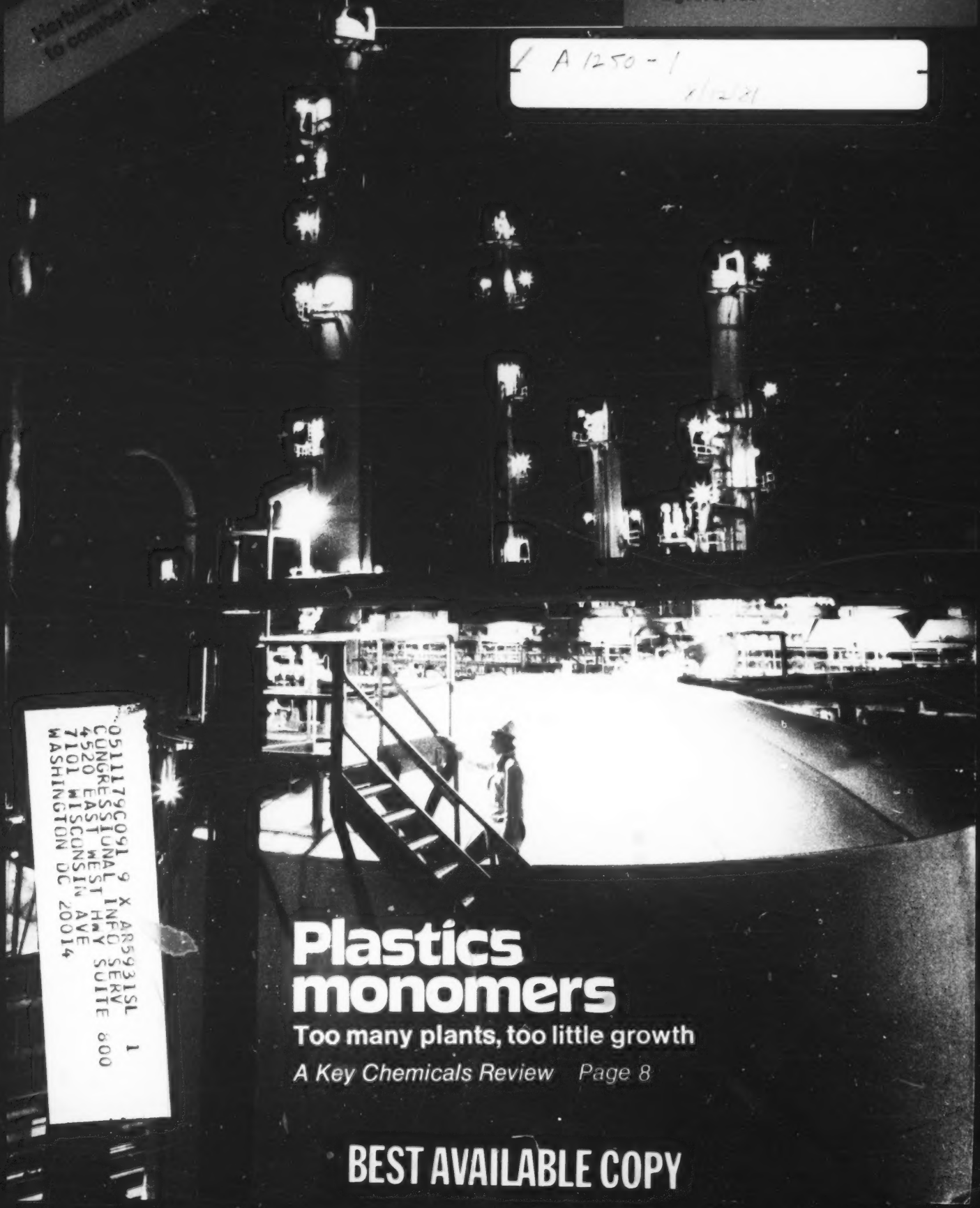

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Plastics monomers

Too many plants, too little growth

A Key Chemicals Review *Page 8*

BEST AVAILABLE COPY

August 3, 1981
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Chemical & Engineering NEWS

Cover: PPG Industries' new vinyl chloride unit at Lake Charles, La.

2 Letters

Concentrates
6 Business
13 Government
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The Departments
36 Meetings
48 Newscripts

News of the Week

- ***Clean Air Act*** *encourages "perverse inefficiency" and discourages new development without proportionate improvements in air quality, according to an industry-sponsored study of the law's effects.* **Page 4**

- ***A fifth NSF-sponsored university-industry research center,*** *the third to focus on polymers, is being set up at Case Western Reserve in Cleveland with funds from NSF and four companies.* **Page 4**

- ***Corco emerges from bankruptcy*** *after more than three years under court jurisdiction, settling claims of $1.4 billion against the Puerto Rican petrochemical firm with cash and paper worth $500 million.* **Page 5**

- ***Ethylene oxide fire*** *in a ruptured railroad tank car burned 40 hours in Conrail's Newark, N.J., yards, causing great disruption before firemen extinguished the blaze with help from CMA's Chemtrec service.* **Page 5**

Business

- ***Outlook for three major plastics monomers****—styrene, vinyl chloride, and toluene diisocyanate—is not bright; excess capacity hinders recovery this year from steep production drop in 1980.* **Page 8**

Government

- ***Amendment that would have cut*** *$70 million from National Science Foundation research funding defeated in House.* **Page 14**

Technology

- ***Supercritical fluid extraction*** *process for separating compounds requires less energy; although more capital-intensive it is attracting many industries.* **Page 16**

- ***ICI's new membrane electrolysis cell*** *for making chlorine-caustic soda will be available on the world market.* **Page 18**

Science

- ***Surfactant vesicles,*** *used to study artificial photosynthesis and drug encapsulation, can be stabilized by polymerization.* **Page 18**

Special Report

The war on weeds *is a never-ending battle although farmers' arsenals are stocked with wide variety of herbicidal chemicals to fight a foe that eats up 10% of U.S. farm production each year.* **Page 20**

Recovery for plastics monomers delayed

Production of styrene, vinyl chloride, and toluene diisocyanate languishes close to 1980 levels in a sea of excess plant capacity

Frustration is the 1981 outlook for three major monomers used in plastics—styrene, vinyl chloride, and toluene diisocyanate (TDI). Production of these materials fell steeply in 1980, ranging from 8 to 20%. In 1981, supposedly past the recession, these three will do well to match 1980 production or slightly exceed it.

Hence, these monomers start the new business cycle in worse shape than their derivative polymers, which are not in very good condition themselves. For one of these, polyvinyl chloride, a bloody shakeout looms in the next few years.

Obviously, something went wrong in some exuberant planning for the monomers in the late 1970's. An extended recession, slow recovery, export reversal, oil price decontrol, and swollen plant capacity have combined to give monomer producers a dreary outlook for the next two years.

It wasn't supposed to be this bad in 1981. Upturns in demand appeared late in 1980 and early this year. A clear recovery seemed under way, just as in 1976 from the 1974–75 recession. However, an unfortunate difference has become clear—a sustained delay this time in recovery to 1979 production levels. For two of these three products, vinyl chloride and TDI, production above 1979 levels might not happen until 1982 or even later.

Worse yet, plant capacity rose for two of the monomers, styrene and vinyl chloride, during 1980. For vinyl chloride, capacity will rise again in each of the next three years, according to announced plans.

Additions to styrene and vinyl chloride capacity within the past year exceed 2 billion lb. None of this will be needed for two years, longer in the case of vinyl chloride. These additions account for an 11% increase for the two larger monomers, much more than estimated growth rates for 1981 and 1982. With long-term growth rates for styrene lowered to about 4% a year and for vinyl chloride to about 3% a year, utilization of the additional capacity could take three to four years.

No capacity additions are expected for TDI which, at about 700 million lb of nameplate capacity, is dwarfed by styrene and vinyl chloride. At best, demand for TDI will grow at 1% annually over the next few years as end-product polyurethane flexible foams go flat in demand and other small uses grow slowly at best.

TDI is replacing propylene oxide in this Key Chemical edition because propylene oxide has become a much more restricted business. Only two U.S. producers of propylene oxide remain; Dow Chemical and Oxirane, part of Atlantic Richfield. As a result, production data are not reported. Two former producers of propylene oxide, Olin and BASF-Wyandotte, ceased production in 1980 and early 1981.

Compared to the other two monomers, TDI is a high-priced chemical, costing two and a half to four times more than the others. Of the three, TDI prices have been increasing whereas styrene list prices have declined and vinyl chloride prices in effect are the same, returning to year-ago levels after a decline.

The 1981 commercial value of these three monomers falls below the forecast made in 1980 (C&EN, July 7, 1980, page 8). This reflects mainly lower production of vinyl chloride in 1980 than expected. For next year, the outlook for the commercial value is up a bit to more than $4 billion. The increase is expected to be fueled by inflation in hydrocarbon costs, with pickup in store for the price of raw material benzene and other aromatics and increases coming in ethylene and chlorine prices. At the moment, pricing in these raw materials is notably weak.

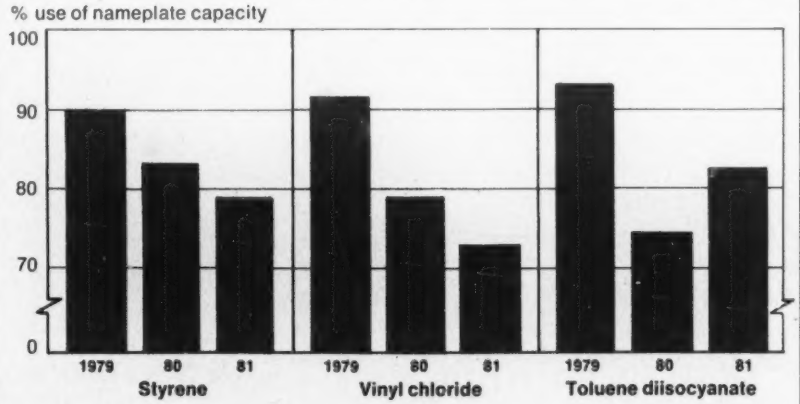
Whether the increased value of these monomers will mean better profitability to producers and therefore justification for the investment in new capacity made recently will be difficult to prove. For example, even with the decline in benzene price in recent months, net income from making styrene has probably declined because of a decline in styrene selling prices under pressure from consumers, who know quite well the large part of styrene production costs coming from benzene.

Currently profit margins in these monomers are down and will remain down until plant operating rates rise. With the relatively low growth rates forecast for these monomers and sizable unused capacity for at least two more years, margins after 1981 will be slow to increase.

For details of the near-term outlook for these three monomers, see the following pages.

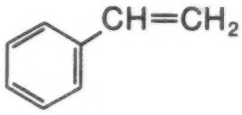
Bruce Greek, Houston

For styrene and vinyl chloride, plant use is even below 1980



Sources: Commerce Department, industry and C&EN estimates

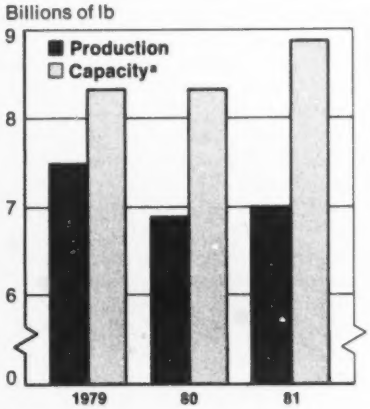
Key Chemicals



Styrene

- ***Demand flat***
- ***Capacity boosted***
- ***Prices falling***

PRODUCTION/CAPACITY



[a] As of first quarter.

HOW MADE

Dehydrogenation of ethylbenzene made either from ethylene and benzene or from petroleum reformate, coproduction with propylene oxide

MAJOR DERIVATIVES

Plastics-oriented polymers 80%, styrene-butadiene rubber 10%

MAJOR END USES

Fabricated plastics 90%

FOREIGN TRADE

Exports—falling to about 800 million lb in 1981, Imports—small

PRICES

List price 37.5 cents a lb

COMMERCIAL VALUE

$2.75 billion for production, 1981

About all U.S. producers of styrene can look forward to this year is matching 1980's poor production of about 7 billion lb. To those in the industry, such a performance is truly disheartening, especially since past slumps have been followed by recovery to a new high the following year. This time, based on performance during this year's first half, styrene can at best pull even with 1980 even if the economy improves late in 1981.

As a result, styrene producers will have two off-years in a row before production has a chance to get back to 7.5 billion lb, the previous record set in 1979. Some pessimists expect a third year below that level in 1982. Such pessimism arises from a hopeless triad of problems—a slump in U.S. exports, weakness in rubber demand, and little or no growth in packaging and other consumer product uses of styrene polymers.

Slumping demand plus new plant capacity put on stream in 1980 by American Hoechst—somewhat offset by the company's shutting down old capacity—will keep the average plant operating rate in the U.S. below 80% of nameplate capacity, now 8.9 billion lb per year. If 1982 output matches 1979, the operating rate will move up a few notches to about 84%.

Fortunately, for some time to come no capacity additions are in view for styrene except minor debottlenecking activities. Most producers are probably above break-even on their current operations but are well below the profit level that would permit capital expenditures for new capacity.

The squeeze on profitability, an almost constant problem in recent years for styrene producers, isn't helped by the fact that most of their customers (or customers of captively produced styrene derivatives) carefully follow the price of benzene, a large part of the raw material price of styrene, and keep the styrene price in line. For example, as benzene's price has weakened in 1981 with continuing decline in demand for gasoline, which uses benzene as an octane booster, so have styrene's actual and list prices. The current styrene list price of about 37.5 cents a lb at plants is down as of the third quarter before being further reduced by temporary voluntary allowances (discounts). Even so, many industry sources feel that the current list prices come much closer to the actual selling prices than in the second quarter.

Hence, an apparent inconsistency has occurred in styrene pricing. Much of styrene's discounting has been in exports. Now, despite lowered domestic list prices, actual U.S. selling prices and effective export prices are increasing. Export volume as a result is taking it on the chin.

Exports are further weakened most by currency conditions but also by revived European protectionism. Strengthening of the dollar relative to European currencies makes styrene more expensive in foreign local currency. In effect, the stronger dollar ends profitability of exporting styrene except at prices far below production cost.

The European duties, both an antidumping levy of 21% and the normal tariff of 6.5%, further reduce attractiveness of styrene exports. In spite of a good first quarter, exports for the whole year may be off 20 to 25% from the nearly 1 billion lb exported in 1980.

In the U.S., packaging of one kind or another dominates uses of styrene. Packing uses many styrene-based polymers, made from styrene alone or as a comonomer. These diverse uses buffer styrene demand, since a slump in one final use frequently is offset by an improvement in another. For example, packaging of electronic components, such as calculators and radios, has been increasing its use of high-impact polystyrenes, but at the expense of acrylonitrile-butadiene-styrene resins. Overall, such uses underlie a growth forecast for styrene of about 5% annually over the next few years.

Offsetting such styrene polymers in growth is styrene-butadiene rubber (SBR). This year, SBR's use of styrene will be no better than in 1980. Longer term, SBR seems to offer growth of no more than 1% a year.

On balance, small growth in U.S. demand will offset a decline in styrene exports in 1981. In other words, it's a year of no recovery—unlike styrene's very strong rebound in 1976 from the severe decline it suffered in the 1975 recession.

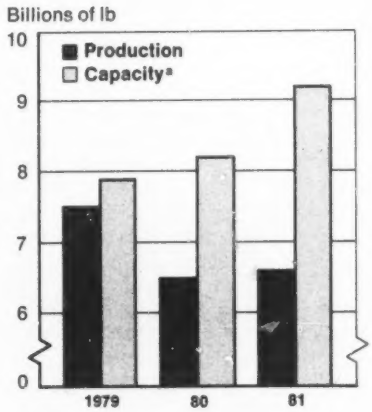
Key Chemicals

Vinyl chloride

$CH_2{=}CHCl$

- ***Demand slow***
- ***Capacity expanding***
- ***Prices flat***

PRODUCTION/CAPACITY



[a] As of first quarter.

HOW MADE

Dehydrochlorination of ethylene dichloride made from ethylene and chlorine

MAJOR DERIVATIVES

Vinyl polymers nearly 100%

MAJOR END USES

Fabricated vinyl plastic items nearly 100%

FOREIGN TRADE

Exports—dropping fast to about 750 million lb in 1981, Imports—negligible

PRICES

List price 22 cents a lb, lowered by discounting

COMMERCIAL VALUE

$1.4 billion for production, 1981

If 1981 looks bad for styrene, it's even worse for vinyl chloride, the main building block for vinyl plastics. Behind this assessment are even lower U.S. plant operating rates than styrene's. As a result, vinyl chloride selling prices will remain lower than needed to justify new investment.

Vinyl chloride production in 1981 will do well to barely exceed 1980 production of 6.5 billion lb. Recent reports show housing starts and building permits dropping again to roughly 1980 recession levels. This means that the outlook for polyvinyl chloride (PVC), heavily dependent on construction markets, is now poorer than had been expected early in 1981, even though PVC output this spring showed some life. As a result, some industry forecasts of 1981 vinyl chloride production are being lowered below 1980's output level by a small amount.

Compounding this grim outlook is an increase in annual nameplate capacity of some 1.5 billion lb for vinyl chloride within the past year. As 1981 opened, Georgia-Pacific started up 1 billion lb of capacity. Then three months ago, PPG Industries added 500 million lb. These additions bring the total in-place vinyl chloride capacity to more than 9.7 billion lb a year, up 18% over capacity a year ago.

No more new capacity is due in 1981. But capacity additions by several producers are scheduled for completion between 1982 and 1984. Whether these expansions are completed on time, or ever, remains to be seen.

If one takes an optimistic view of 1981 production, say 6.6 billion lb, and adjusts operable capacity for the entire year to 9.2 billion lb to account for possible startup problems and partial-year operation, the average operating rate will be 72%. In 1980, based on estimated reported production of 6.5 billion lb and a nameplate capacity of 8.2 billion lb, the operating rate was almost 80%. In a healthier time, the 1979 rate was more than 91%, pushed to the limit by strong demand for all kinds of chemicals.

Prospects for vinyl chloride production in 1982 seem better. It's expected that business will improve late in 1981 and extend the improvement into 1982.

Based on current opinion that some deferred demand will surface next year, vinyl chloride's plant operating rate could move up a few percentage points. A bit more than 500 million lb of capacity is scheduled to come on stream in 1982, but this should have little influence on the total operating capacity for the year.

Future oversupply appears possible for vinyl chloride through the mid-1980's, springing from several factors. One was the high operating rates in the late 1970's. Such rates seemed to justify additional investment, especially with weak pricing in raw material chlorine, which has become the poor relative of coproduct caustic soda. To chlorine producers, captive vinyl chloride appears to be another place to put chlorine to help rescue operating rates for chlorine-caustic plants.

Another factor in the vinyl chloride building binge was anticipation of high exports. But decontrol of U.S. crude oil prices, which raised energy and feedstock costs, made vinyl chloride less competitive in world markets, even to foreign buyers who saw it as a lower-cost way to avoid direct investment in chlorine. Because of such changing costs, exports of vinyl chloride are expected to continue a downward trend. In effect, this will force more product into a saturated U.S. market.

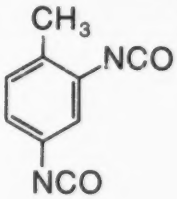
Most U.S. markets for vinyl chloride as PVC are quite mature. With a couple of exceptions, growth rates for PVC markets are all small even under good economic circumstances. At present, with housing and auto sales in a slump, the outlook for PVC demand is worse than normal.

When PVC demand growth resumes, the best numerical, if not percentage, increases are expected in the favored product form of pipe, fittings, and conduit. This product category accounts for 40 to 45% of total PVC consumption in the U.S. Its share should hold, if not grow slightly, with time as costs continue to favor PVC over competing pipe.

Overall, with slumps in vinyl chloride and PVC exports, vinyl chloride production will do well to match a depressed 1980. Added plant capacity will keep down profitability, and the question of the wisdom of continued capacity expansion grows more important.

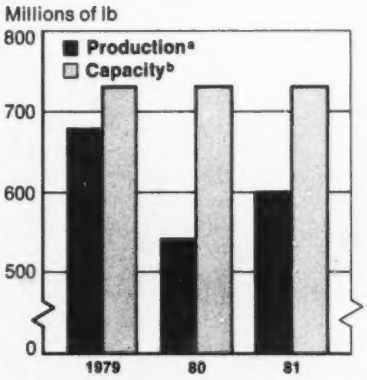
Key Chemicals

Toluene diisocyanate (TDI)



- ***Demand recovering***
- ***Capacity flat***
- ***Prices raised***

PRODUCTION/CAPACITY



a Mostly 80/20% mixtures of isomers, but includes small amounts of 65/35% mixtures.
b As of first quarter.

HOW MADE

Nitration of toluene, followed by reduction to diamine, reaction with phosgene, purification, and recovery of coproduct hydrochloric acid

MAJOR DERIVATIVES

Polyurethanes almost 100%

MAJOR END USES

Flexible polyurethane foam products 85%, polyurethane coatings 5%

FOREIGN TRADE

Exports—to stay about 175 million lb in 1981, imports—negligible

PRICES

Posted price about 93 cents a lb

COMMERCIAL VALUE

$500 million for production, 1981

U.S. producers of toluene diisocyanate (TDI) are beginning to recover from the shock of a more than 20% drop in demand in 1980. 1981 certainly will be no banner year, but a 10% upswing seems probable.

This year, production of TDI likely will top 600 million lb. Just about all of this will be reacted with various polyols to make polyurethane foams, coatings, and elastomers. The upside limit for 1981 production seems to be 625 million lb, depending on exports. The downside extreme will be about 575 million lb if automobile production falls and exports slump unexpectedly. If 1981 TDI production reaches or slightly exceeds 600 million lb as now forecast, it will still be 12% below the previous production high of 680 million lb in 1979. Some industry sources don't expect 1979 production to be exceeded even in 1982 because of little growth in U.S. demand and a strong probability for a decline in exports.

The three years, 1980–82, are in marked contrast with 1979, when demand for TDI was so great that producers had it on allocation part of the time. Such good times for TDI producers might not return by 1982.

Slowed demand for TDI makes current estimates of demand prove reasonably accurate. For 1981, in-place nameplate capacity will run at about 82%. By contrast, in 1979 producers ran all-out most of the year at 93% of nameplate capacity, well above the normal rate of 85 to 90%. TDI plants are considered as difficult as any in the chemical industry to operate at high levels because of complex processing steps and tricky, generally proprietary, technology for isomer separation and final purification.

Although TDI is in poor shape, as are many other large-volume chemicals, producers should be credited for not making the situation worse. Perhaps some of the reason for this restraint is that TDI capacity in the U.S. has such a large foreign ownership, about half. The worldwide growth prospective in the business may temper U.S. planning.

At the time of high production and allocation in 1979, plenty of incentive existed for TDI producers and potential new producers to invest in new capacity. However, other than debottlenecking efforts, no new capacity has been added in the past two years, and none is scheduled to be built in 1982. This prospect could lead TDI back to high capacity use in a year or two and to a supply crunch toward the mid-1980's.

The shift to the present overcapacity for TDI resulted from the same changes in consumer demand that hit most other chemical products in 1980 and 1981. With dominant uses in flexible polyurethane foams, TDI suffers from the decline in new auto and housing demand. The current outlook for these items is about flat.

In the future, even if end-use unit volume grows, demand for polyurethane foams may not necessarily grow with it. For example, down-sizing of cars and changes in seating fashions have been reducing the amount of urethane foams needed in cars.

Housing demand for urethane foams comes mainly in furniture, bedding, and to a small extent in carpet underlays. Although replacement furniture can be important, the major push in furniture demand comes from new housing. That's not good for polyurethane in 1981.

The other applications for TDI as polyurethanes account for less than 15% of total use. The two largest are components of several kinds of coatings and cast elastomers. Neither of these applications has been showing large growth rates, and they are not expected to increase present rates much, if at all.

The polyurethane coatings which use larger quantities of TDI are those going to relatively severe use conditions—finishes for floors, sealers for wood and concrete, or paints for trucks which must be left out in the weather.

Cast urethane elastomers go mainly to industrial mechanical rubber goods but do include consumer products such as roller skate wheels. High costs of development in these applications tend to limit growth because selling prices must be high as well to include recovery of development and technical support costs.

With slowness in the U.S. economy and potential loss of some exports, the near-term outlook for TDI must be called flat at best. Returning to 1979 production levels will take beyond 1981.

NOTE

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Second-quarter chemical earnings ease a bit from first quarter Page 10

Chemical & Engineering NEWS

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8/24/81

Chemistry through an electron microscope

Page 40

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Chemical & Engineering NEWS

Cover: Black and white micrograph images of beta rhombohedral boron shown against colored representation of a calculated electron density map of the same compound. For more details, see page 41.

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News of the Week

- ***FTC rules four firms guilty of price-fixing*** *and anticompetitive marketing practices in sale of lead gasoline additives; potentially far-reaching decision forbids advance notice of price changes.* ***Page 6***
- ***Changes in long-term employment patterns*** *of Ph.D. scientists and engineers are evident, according to survey conducted by National Research Council.* ***Page 6***
- ***Four EPA regulations will be reviewed*** *at the direction of the Administration's Task Force on Regulatory Relief; among targets are rules on lead in gasoline and premanufacture notification.* ***Page 7***
- ***Du Pont's takeover of Conoco*** *is in final stages, as the chemical firm seeks approval from its own stockholders for merger and settles questions as to fate of Conoco shares acquired by Seagram.* ***Page 7***

Business

- ***Combined second-quarter earnings*** *of 40 largest U.S. chemical companies were up 24% from same period in 1980, but down slightly from first quarter of 1981, indicating some weakness.* ***Page 10***

International

- ***Canadian chemical companies*** *reported higher sales for the first half of 1981, but combined earnings were off, suffering from inflation, high energy costs, and the slumping Canadian dollar.* ***Page 18***

Government

- ***Budget reconciliation bill*** *passed by Congress left funding for research relatively unscathed despite attempts to hold down federal spending.* ***Page 22***

Science

- ***Cancer risk factors*** *were evaluated in study which concludes that there is no epidemic in U.S. and that tobacco use is greatest avoidable risk.* ***Page 32***

Technology

- ***Electronic balance market*** *is growing rapidly as manufacturers race to improve data-handling systems and special functions of top-loading models.* ***Page 37***
- ***Anaerobic wastewater treatment process*** *being licensed by Celanese is energy-efficient, produces less sludge.* ***Page 38***

Special Report

High-resolution microscopy *allows chemists to probe the structure of solids in detail as limits of resolution approach atomic level with improvements in transmission and scanning electron microscopes.* ***Page 40***

ACS News

- ***"What's Happening in Chemistry"*** *presents chemical news of 1980.* ***Page 63***

FTC RULES AGAINST FOUR FIRMS ON PRICING

A Federal Trade Commission administrative law judge last week ruled that four producers of lead additives for gasoline could not publicize price increases before they take effect. The decision could have far-reaching implications if applied to other chemical businesses, since it strikes at the heart of much of the chemical industry's pricing process.

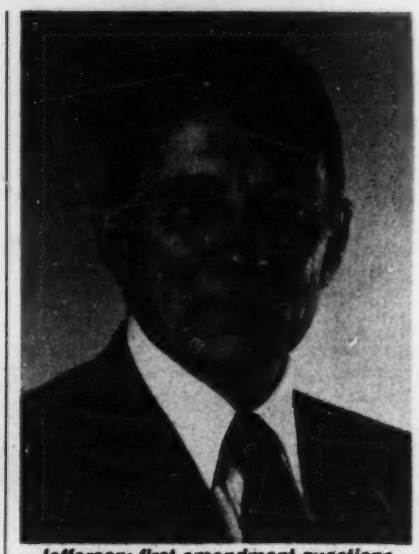
The four companies in the case are Du Pont, Ethyl Corp., Nalco Chemical, and PPG Industries.

Chief judge Ernest G. Barnes ruled that the four producers have engaged in anticompetitive practices that have enabled them to maintain identical prices for their products. The decision upholds FTC's charges, filed in 1979, that between 1974 and 1979, the four companies violated antitrust laws using unfair anticompetitive marketing practices. This included signaling future price increases by giving advance notice to the press.

The complaint also said that the four companies sold lead additives on a uniform price basis, under which each company had one price for all customers. Freight, included in the price, was averaged for all customers, regardless of location, although actual delivery costs vary greatly. FTC also charged that Ethyl and Du Pont included "most favored nation" clauses in their contracts. Under these clauses, customers are guaranteed that they will receive the lowest available price. FTC said that these clauses, instead of lowering the price, were used as a defense against discounting by the producers.

Barnes' order prohibits the companies from announcing a price change to customers before the effective date; announcing sales information to any of the other producers, except in connection with a bona fide sale between them; announcing a price change to the press until 30 days after the change; using a pricing formula that systematically matches a competitor's prices; and using a "most favored nation" clause in sales or delivery contracts.

The order also requires the companies, when offering a delivered price, to inform the customer of the transportation cost included in the price or allow the customer to furnish transportation for the shipment.



Jefferson: first amendment questions

The advance notice of price information is the heart of the case and breaks new ground in antitrust considerations. The judge writes that advance notice of price increases "gives rivals an opportunity to respond in a way that reduces uncertainty about industry price levels before the initiator's new price goes into effect." Thus, the company can test the water to see if the price change will last and if rivals will follow suit. He notes that for 24 price increases between 1974 and 1979, the increases were announced on the same day and were identical in 20 instances. In the other four, identical prices were announced within a day or two of each other.

If the order were to be broadened to other products, industry sources say, it could have an effect, not only on the pricing policies of producers, but also on those of customers. Advance notice of price increases always has been justified as giving customers time to plan and to adjust their own pricing schedules.

For instance, price hikes planned for January of this year and announced at the beginning of December gave customers a chance to do advance buying at 1980 prices.

Of the four producers involved in the case, three—Du Pont, Ethyl, and Nalco—have said they will appeal. PPG probably will follow suit.

Du Pont chairman Edward G. Jefferson says, "We and outside counsel remain convinced that these common industry practices are legal. We continue to believe the practices banned by the judge's order are of benefit to our customers. Moreover, any FTC action to prohibit industry from releasing pricing information to the news media raises serious first amendment questions."

Nalco says that it continues to believe that this is a "new and unwarranted interpretation of the law" and does not believe that it has engaged in any acts or practices that constitute unfair methods of competition. Ethyl says that it does not believe that the judge's finding are consistent with the facts presented. □

Job patterns of Ph.D. scientists surveyed

Continuation in some long-term changes in employment patterns of Ph.D. scientists and engineers is evident in the latest survey of doctorate holders reported by the National Science Foundation. The survey—currently for the period 1977 to 1979—has been conducted biennially since 1973 for NSF and other federal agencies by the National Research Council.

Job opportunities in science and engineering activities continued to grow between 1977 and 1979, although at a bit slower rate than earlier in the decade. Employment of such Ph.D.'s reached 287,100 in 1979, growing at an average annual rate of 5% between 1977 and 1979, compared with 8% per year between 1973 and 1975.

But although Ph.D. employment continued to grow, so did a long-term shift away from educational institutions to business/industry. Between 1977 and 1979, employment of Ph.D. scientists and engineers in business/industry grew 16%—about two and a half times the rate for educational institutions, NSF notes.

Another change that shows up in the survey is a shift in utilization patterns away from physical and mathematical sciences. NSF points out that these short-term shifts are the most recent indicators of more

Ph.D. scientists/engineers shift from physical sciences

	Employment			% change	
	1973	1977	1979	1977–79	1973–79
Physical sciences	44,200	51,300	54,400	6%	23%
Mathematical sciences	11,700	13,600	14,100	4	20
Computer sciences	2,700	5,700	6,600	16	146
Environmental sciences	10,100	12,600	14,100	12	40
Engineering	34,200	42,400	47,100	11	38
Life sciences	55,600	68,100	76,000	12	37
Psychology	23,400	31,300	35,000	12	50
Social sciences	24,400	36,000	39,800	10	63

Source: National Science Foundation

fundamental long-term trends. The most rapid science and engineering employment growth rates for 1973 to 1979 have been in computer sciences, psychology, and social sciences, and the slowest in physical and mathematical sciences. The largest absolute growth in employment was among life scientists.

Across all sectors, R&D replaced teaching as the largest work activity in 1979. And shifts in activities within R&D reflect, in part, the shift toward business/industry employment, with a more rapid increase in the number engaged in development/design (up 77%) than in basic and applied research (up 33%). Also, within research, there was a shift away from applied research in business/industry and from basic research in academia—both toward development/design. □

EPA directed to review four regulations

Once more into the fray. With its tax and budget-cut battles won, the Reagan Administration again is focusing on the third integral part of its economic recovery program—regulatory relief.

Among the 30 regulations selected for this round of reviews are a number of environmental regulations. But at a press conference announcing the review, Vice President George Bush, head of the Presidential Task Force on Regulatory Relief, emphasized that "nothing in our approach is intended to diminish the quality of the environment. We're not prejudging whether anything in these regulations is bad. We're going to review them. Complaint after complaint comes in that we've gone too far . . . that there has to be a better way—and that is what we're trying to find."

The Environmental Protection Agency has been directed by the task force to review four of its regulations. One of these is its recent order reducing the maximum amount of lead that can be added to gasoline from 0.8 g per gal to 0.5 g per gal. According to documents issued by the task force, the rule is being reviewed because the phasedown imposes a substantial energy penalty as a result of the increased amount of crude oil required to produce low-lead or unleaded gasoline. It also imposes onerous capital requirements on small refiners.

In addition, the documents note, the gradual decline in the number of vehicles using leaded gasoline has reduced lead emissions by nearly the amount originally sought by the phasedown program, and this may offer adequate protection for most of the country where lead concentrations in the air are already below the level judged safe by EPA.

The second regulatory area EPA has been directed to review is its premanufacture notification requirements under the Toxic Substances Control Act, which, the documents say, hold the potential for obstructing the introduction of new chemicals. EPA will consider waiving or relaxing its requirements for chemicals that do not pose an unreasonable risk to health or the environment.

Bush: trying to find better way

The other two areas the agency has been directed to review are its pesticide registration process, which the documents say appears to delay unnecessarily the distribution of new pesticide products, and its consolidated permit program, whose implementation has resulted in greatly increased complexity, including often unnecessary procedural requirements and information burdens. □

Du Pont wrapping up takeover of Conoco

The prize is at hand in the three-month quest for control of Conoco. The runaway winner in the bidding, Du Pont, faces its own stockholders this week for approval of the extraordinary merger, which would make oil and natural gas the largest business of the combined firm (C&EN, July 13, page 6).

Several preliminary moves after the bidding war between Du Pont, Mobil, and Seagram cleared up some of the major questions remaining on who would own exactly what of Conoco or Du Pont.

Settling one question, Du Pont exercised its option to buy 15 million additional Conoco shares held by Conoco itself at a price of $87.50 per share. Du Pont obtained the option in its original merger negotiations with Conoco. With this stock, Du Pont held about 63 million Conoco shares, or 62% of the total shares outstanding of about 102 million.

More than half the Conoco shares not yet in Du Pont hands belong to Seagram, which finished its tender offer with about 28 million Conoco shares. Seagram says it will tender these shares to Du Pont in return for Du Pont stock. The result would be Seagram's becoming Du Pont's largest individual stockholder with more than 18% of the total. Du Pont says it looks forward to a constructive relationship with Seagram.

Since Seagram seems to be content with a holding in Du Pont, it appears there will be no immediate deal for Seagram to purchase Conoco's big coal operation. Conoco also denies that any such selloff was in the making, although coal was considered a possible prize for Seagram during the tender battle. □

Chemical earnings up, but still weak

Although profits at major chemical companies soared 24% from last year, they were down slightly from the first quarter of 1981

William J. Storck
and William F. Fallwell
C&EN, New York

Chemicals in the second quarter looked good on the surface. Earnings at major U.S. chemical companies were up 24% from second-quarter 1980. Chemical earnings, excepting petrochemical earnings at oil companies, improved, as did chemical profits at the more diversified companies with an interest in chemicals.

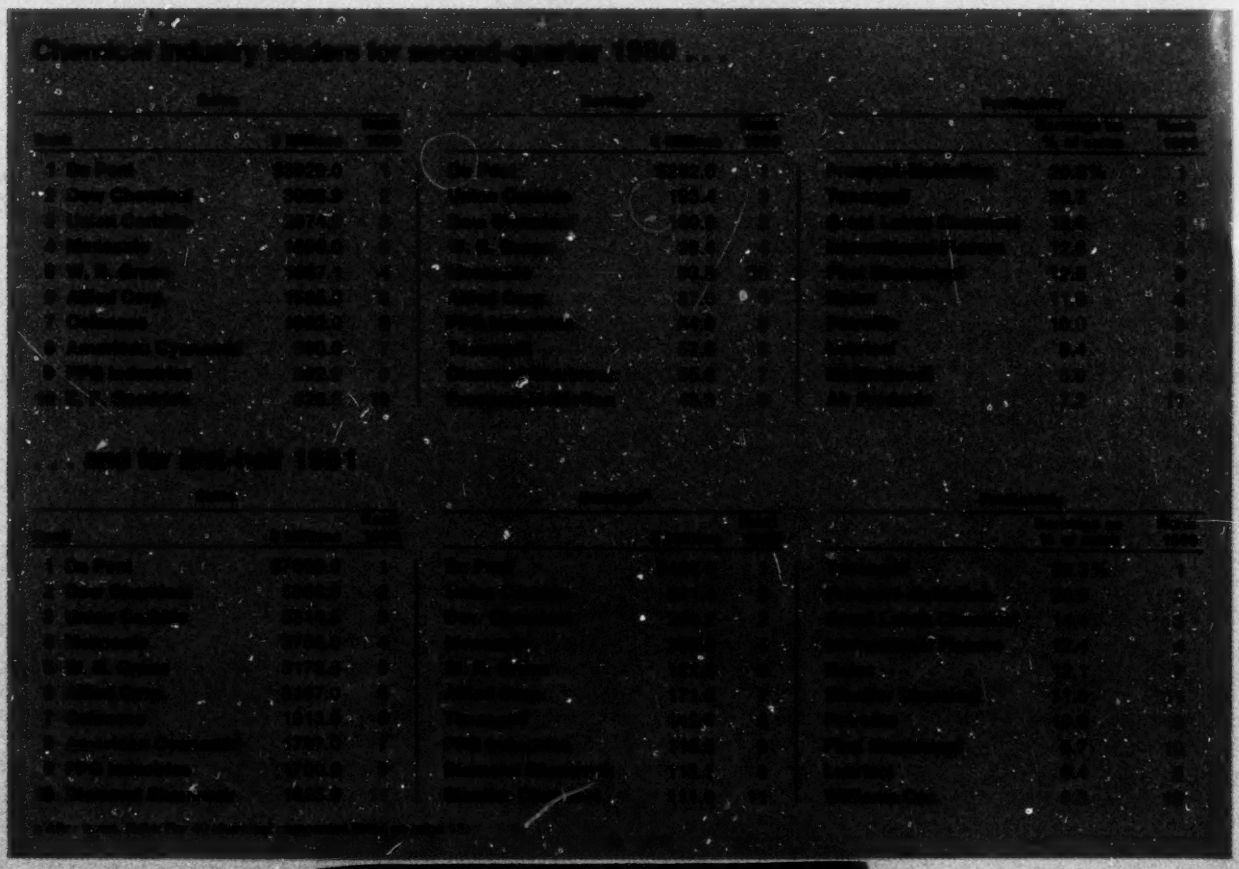
However, in spite of a big earnings increase on a year-to-year basis for the 40 largest U.S. chemical companies, their performance on a quarter-to-quarter basis is not so good. Earnings for the 40 companies were actually down about 1% from the first quarter of 1981. This is unusual because second-quarter earnings are usually higher than those in the first quarter, and the drop this year indicates a certain amount of weakness in the chemical economy through the first half.

In fact, the quarter-to-quarter change this year is probably more significant than the change from the second quarter of 1980, which was much depressed as chemicals slid into last year's recession.

What second-quarter performance really means is that the chemical industry recovery from the 1980 recession has hit a plateau. Although financial results just out from chemical producers are the proof, they aren't all that surprising. Ever since early spring, new orders have been soft and price rises increasingly in trouble. Interim government statistics have borne this out, showing flat shipments and production, gradually rising inventories, and a reduced rate of price inflation.

Behind this pause is the same problem afflicting a great many U.S. industries: super-expensive credit. With interest rates close to all-time records, big-ticket products simply don't sell very easily—particularly automobiles and new houses, which use large quantities of chemicals. Even with its many specialty product lines, the chemical industry cannot escape some damage from pervasive weakness in the durables part of the general economy.

At the moment, industry thinking has changed reluctantly on the outlook for the rest of 1981. Whereas the conventional wisdom six months ago



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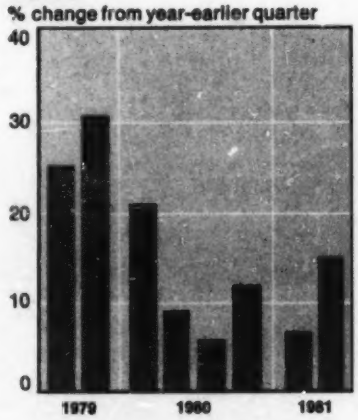
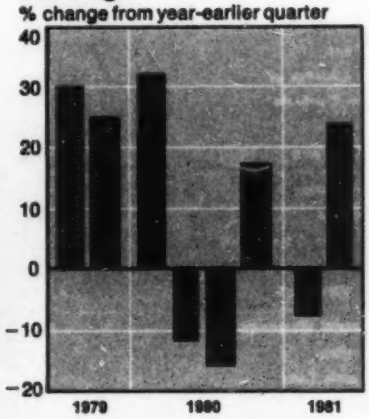
Chemical industry 1981 second-quarter results

- Sales up 15% from year ago
- Earnings jumped 24%
- Profit margins rose
- Production was up
- Price increases slowed

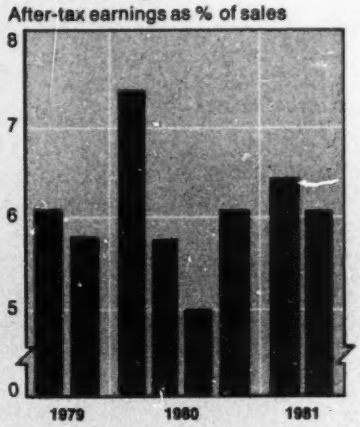
Sales
% change from year-earlier quarter



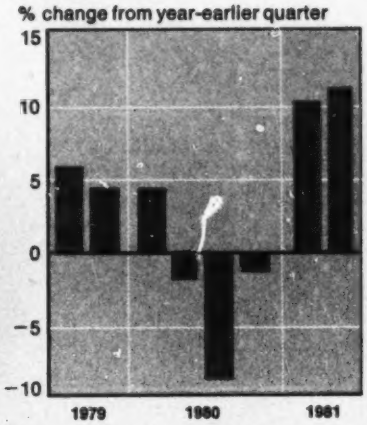
Earnings
% change from year-earlier quarter



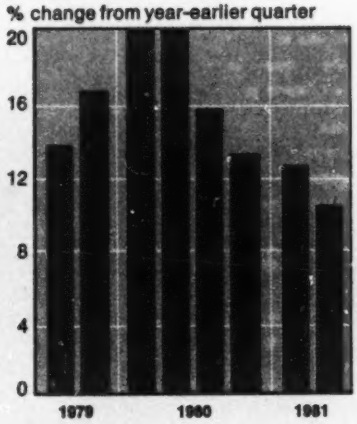
Profit margins
After-tax earnings as % of sales



Production
% change from year-earlier quarter

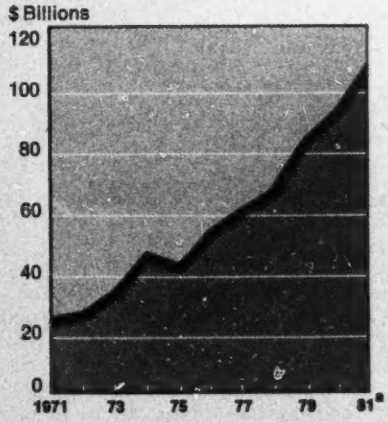


Prices
% change from year-earlier quarter

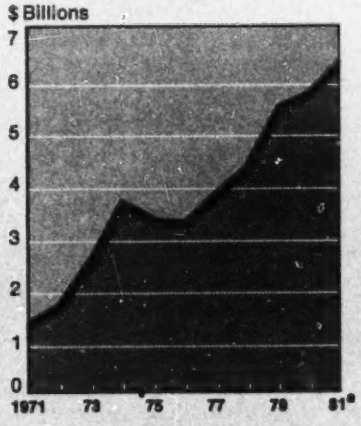


Chemical sales this year likely will top $100 billion, a 15% increase, whereas earnings will rise only 10%; profit margins will fall to 1977 levels

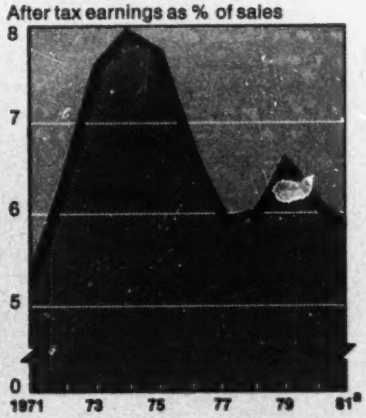
Annual sales
$ Billions



Annual earnings
$ Billions



Annual profit margins
After tax earnings as % of sales



a C&EN estimates. Note: All sales, earnings, and profit margin data are based on the combined performance of the 40 chemical companies listed on page 12.

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Earnings gain for large companies outpaced that for smaller firms in second quarter

	SECOND-QUARTER 1981						FIRST-HALF 1981			
	Sales	Earnings	Change from 1980		Profit margin[a]		Sales	Earnings	Change from 1980	
	($ millions)		Sales	Earnings	1981	1980	($ millions)		Sales	Earnings
Du Pont	$ 3,929.0	$ 262.0	14%	51%	6.8%	5.1%	$ 7,606.0	$ 466.0	8%	12%
Dow Chemical[d]	3,066.9	160.0	22	−7	5.2	6.8	5,963.8	288.9	12	−28
Union Carbide[e]	2,674.9	193.4	13	29	7.2	6.3	5,314.5	371.4	8	nc
Monsanto	1,865.0	93.8	20	304	5.0	1.5	3,756.0	269.8	11	44
W. R. Grace	1,687.1	99.4	9	18	5.9	5.4	3,173.8	182.5	8	21
Allied Corp.	1,585.0	87.0	16	19	5.5	5.4	3,167.0	171.0	15	21
Celanese	1,002.0	41.0	25	64	4.1	3.1	1,913.0	77.0	16	26
American Cyanamid	900.0	42.2	8	29	4.7	3.9	1,787.0	89.3	7	26
PPG Industries	892.9	64.0	19	61	7.2	5.3	1,700.0	116.5	10	23
B. F. Goodrich[f]	828.5	20.6	10	106	2.5	1.3	1,608.9	29.0	7	−4
Diamond Shamrock	786.3	55.8	6	5	7.1	7.2	1,623.8	113.5	11	8
Hercules	712.0	33.5	14	22	4.7	4.3	1,380.0	69.0	11	14
Williams Cos.	578.2	37.9	1	−23	6.6	8.5	1,073.9	89.5	2	9
Rohm & Haas[g]	545.4	33.4	17	24	6.1	5.8	1,024.1	58.2	13	7
Olin	544.6	32.9	12	21	6.0	5.6	1,066.3	61.3	11	25
International Minerals	520.4	29.8	4	−6	5.7	6.3	1,083.4	76.8	13	−16
Ethyl Corp.[h]	453.4	23.6	3	−2	5.2	5.5	878.6	44.1	nc	−3
Air Products	387.6	28.0	9	4	7.2	7.6	800.6	64.9	9	6
Stauffer Chemical	377.2	23.1	6	16	6.1	5.6	1,006.5	111.0	7	24
Witco Chemical	335.5	10.3	20	−10	3.1	4.0	659.1	16.2	17	−25
Akzona	314.0	4.8	14	233	1.5	0.6	622.9	7.5	16	11
Pennwalt	308.7	12.7	8	17	4.1	3.8	603.7	15.3	4	−34
Texasgulf[i]	278.3	57.6	16	−3	20.7	24.6	553.6	142.5	6	−29
Reichhold Chemicals[j]	254.3	5.5	19	2586	2.2	0.1	493.1	9.5	10	116
Lubrizol	240.9	20.2	−1	−32	8.4	12.1	465.1	39.1	nc	−33
Freeport-McMoRan	208.2	43.3	33	2	20.8	27.3	432.8	89.0	35	4
Thiokol	177.6	8.8	21	16	5.0	5.2	350.1	17.0	19	1
Nalco Chemical	164.1	19.6	9	11	11.9	11.7	320.9	38.7	8	14
First Mississippi	137.1	17.1	44	94	12.5	9.3	201.3	17.5	47	32
Mallinckrodt	127.4	10.2	17	13	8.0	7.4	248.7	20.3	12	13
International Flavors	120.3	15.1	−3	−21	12.6	15.5	243.7	30.2	−1	−19
Liquid Air[k]	109.0	7.2	6	13	6.6	6.2	218.6	16.4	4	12
H. B. Fuller	84.7	3.7	12	32	4.4	3.7	162.8	6.7	13	52
Petrolite	74.9	7.5	16	9	10.0	10.7	145.8	14.5	18	20
Crompton & Knowles	66.1	2.4	8	14	3.6	3.4	126.0	4.2	3	8
Stepan Chemical	56.0	1.9	49	31	3.4	3.8	105.6	3.0	37	51
Loctite	55.7	2.6	8	−57	4.7	11.6	112.3	5.6	10	−54
Essex Chemical	52.1	3.5	39	150	6.7	3.7	92.0	4.4	30	110
Great Lakes Chemical	34.5	4.7	30	19	13.6	14.7	69.3	10.0	15	8
Philip A. Hunt	28.6	1.2	3	−43	4.0	7.3	54.7	1.3	1	−62
Total 20 largest companies	**$23,671.9**	**$1371.7**	**14%**	**28%**	**5.8%**	**5.2%**	**$46,586.3**	**$2765.9**	**10%**	**7%**
Total 20 other companies	**$2,902.5**	**$249.6**	**23%**	**5%**	**8.6%**	**10.1%**	**$5,623.0**	**$492.7**	**15%**	**−9%**
Grand total	**$26,574.4**	**$1621.3**	**15%**	**24%**	**6.1%**	**5.7%**	**$52,209.3**	**$3258.6**	**10%**	**4%**

a After-tax income as percentage of sales. b Fully diluted before nonrecurring items and extraordinary charges for operations. c As of July 31. d Excludes nonrecurring gain of $21 million in second-quarter 1981. e Excludes $217.3 million nonrecurring gain in first-quarter 1980. f Excludes nonrecurring gain of $18 million in first-half 1981. g Excludes $13.4 million charge in

called for a slow first half followed by a marked pickup in the second, the consensus now is that the entire year could turn out in the doldrums. Certainly no fresh wind has blown in for the third quarter.

This lag will have some important consequences. Most generally, the chemical industry's new business cycle, starting with expansion, is behind schedule by at least half a year. That will upset a lot of fairly rosy earnings forecasts for 1981. It also will keep the brakes on capital spending, the chemical industry's most important use of free-standing funds, despite the new incentives in legislation from Washington. It will not, apparently, affect the industry's big planned increase this year in R&D.

Combined earnings for the 40 companies were up 24% in the second quarter from a year earlier to $1.62 billion. Combined sales for the 40 companies topped $26.57 billion in the quarter, a gain of 15% from the same period a year ago. Profit margins rose to an average 6.1% from 5.7% last year.

For the second straight quarter, the

FIRST-HALF 1981		12-MONTH RUNNING DATA				Earnings per share[b]		STOCK MARKET DATA[c]					
Profit margin[a]		Change from 1980		Profit margin[a]			Recent	Stock price	Recent 12 months		Price earnings ratio	Annual indicated	Dividend yield, %
1981	1980	Sales	Earnings	1981	1980	2nd qtr	12 months	July 31	High	Low	July 31	dividend	of price
6.2%	6.0%	7%	−13%	5.4%	6.6%	$1.67	$5.06	45½	56	36	9	$2.40	5.3%
4.8	7.5	10	−19	5.7	7.8	0.84	3.68	31¼	39	30⅛	8	1.80	5.8
7.0	7.5	7	nc	6.3	6.7	2.86	10.43	56¼	62⅛	43	5	3.40	6.0
7.2	5.6	9	17	4.8	4.5	2.32	8.98	74	87½	50¼	12	3.80	5.1
5.8	5.1	12	15	4.9	4.8	2.05	6.60	48⅛	63½	41⅝	7	2.60	5.4
5.4	5.1	12	46	5.6	4.3	2.40	9.24	53¾	61¾	46⅞	7	2.40	4.5
4.0	3.7	11	10	3.8	3.9	2.39	8.73	63½	69¼	48⅝	7	3.80	6.0
5.0	4.2	8	15	5.0	4.7	0.88	3.88	30¼	36½	26	8	1.60	5.3
6.9	6.1	7	12	6.9	6.6	1.91	6.94	44½	58¼	32¾	6	2.36	5.3
1.8	2.0	5	6	1.9	1.9	1.03	4.22	24½	28⅛	20⅛	6	1.56	6.4
7.0	7.2	17	−8	5.9	7.4	1.00	3.42	34½	39⅝	27¾	10	1.68	4.9
5.0	4.8	5	nc	4.9	5.2	0.76	2.91	24⅛	26⅜	18	8	1.32	5.5
8.3	7.8	7	11	6.5	6.3	1.27	5.18	28⅞	49⅞	25¾	6	1.20	4.2
5.7	6.0	10	2	5.4	5.9	3.14	8.32	65¼	71¾	45⅝	9	2.80	4.3
5.7	5.1	7	14	4.4	4.1	1.37	3.63	23⅝	27	17½	7	1.20	5.1
7.1	9.5	15	7	7.7	8.3	1.09	6.13	42½	66½	38⅜	7	2.60	6.1
5.0	5.2	−1	−7	5.1	5.4	1.19	4.36	26⅞	36½	25⅜	6	1.50	5.6
8.1	8.3	10	5	7.8	8.2	0.98	4.23	37¼	59¼	36¾	9	0.80	2.1
11.0	9.5	9	3	8.1	8.5	0.52	3.25	24	27¾	17⅜	7	1.32	5.5
2.5	3.8	18	−17	2.8	4.0	1.05	3.69	28¼	33¾	26	10	1.60	5.7
1.2	1.3	6	−68	0.5	2.4	0.39	0.46	13¾	15½	10	30	0.80	5.8
2.5	4.0	5	−11	3.4	4.1	1.23	3.91	28¼	36	25¾	8	2.20	7.8
22.3	33.7	20	48	27.9	22.7	1.60	7.32	53⅛	57⅞	19¼	7	1.00	1.9
1.9	1.0	4	159	2.3	0.9	0.69	2.64	13⅝	16	11	5	0.48	3.5
8.4	12.5	7	−16	10.0	12.7	0.51	4.21	26½	41⅝	24⅝	6	1.08	4.1
20.6	26.8	39	40	21.2	21.1	0.63	3.69	32½	40½	29⅜	9	0.60	1.8
4.8	5.8	23	−22	4.3	6.7	0.76	2.67	31⅞	39	25¾	12	1.10	3.5
12.1	11.4	6	17	12.1	11.0	0.97	3.84	49⅜	58¼	38⅛	13	2.00	4.8
8.7	9.7	47	41	8.3	8.7	0.80	1.65	18¾	30¾	15¼	11	0.24	1.3
8.2	8.2	13	11	8.1	8.2	0.69	3.53	33¾	41⅝	23⅝	10	1.00	3.0
12.4	15.2	1	−14	12.6	14.8	0.42	1.99	19⅛	27½	17⅞	12	0.92	4.8
7.5	6.9	9	4	6.8	7.1	0.68	2.29	22¼	34½	22¼	10	1.60	7.2
4.1	3.0	13	45	3.9	3.0	0.81	2.65	24⅜	24½	11½	9	0.48	2.0
10.0	9.8	25	43	9.9	8.7	0.63	3.97	33¾	44¾	31	9	0.80	2.4
3.3	3.2	2	−9	3.1	3.6	0.72	3.02	17⅝	18¾	11¾	8	0.96	5.4
2.8	2.6	23	67	3.5	2.6	1.00	2.51	34¼	43¾	16⅞	14	1.00	2.9
5.0	12.0	7	−60	4.9	13.0	0.26	1.05	24¼	38	23	23	0.56	2.3
4.8	3.0	26	103	4.6	2.8	0.94	2.58	20	20¼	11¾	8	0.80	4.0
14.4	15.3	9	3	14.6	15.4	0.65	2.76	47¾	58½	39	17	0.44	0.9
2.4	6.4	−1	−74	1.9	7.1	0.20	0.34	9⅜	13½	8⅞	45	0.40	4.3
5.9%	6.1%	9%	[illegible]	5.4%	5.9%								
9.0%	11.1%	13%	15%	9.2%	9.0%								
6.2%	7.0%	9%	2%	5.8%	6.2%								

second-quarter 1981 and $7.6 million nonrecurring gain in first-quarter 1981. h Excludes $6.8 million charge in second-quarter 1980 and nonrecurring gain of $7.3 million in first-quarter 1980. i Excludes $18.6 million nonrecurring gain in first-half 1981. j Excludes $2.4 million charge in second-quarter 1981. k Excludes $2 million gain in second-quarter 1980. nc = no change.

larger companies outperformed the smaller companies. The 20 biggest companies on the list had an earnings gain of 28% to $1.37 billion. This increase came on a sales gain of just 14% to $23.67 billion.

By way of contrast, the smaller companies on the list had a smaller earnings gain on a larger sales gain for the quarter. Earnings at the 20 smaller companies totaled nearly $250 million, a 5% gain from the second quarter last year. However, sales at the smaller companies increased 23% to a total of $2.90 billion.

The huge increase in earnings at the 40 chemical companies in the second quarter made the year-to-year change for the first half positive. After being off about 8% in the first quarter, chemical company earnings improved an average of 4% for the first half. Earnings for the 40 companies in the first six months totaled $3.26 billion, compared with $3.12 billion in the first half of 1980. Sales for the 40 companies increased a much faster 10% to $52.21 billion in the first six months this year. The result was that profit margins were driven down to an

Earnings are up at most chemical-producing oil and natural gas companies

	% Chemical sales	SECOND-QUARTER 1981 Sales ($ millions)	Earnings	Change from 1980 Sales	Earnings	Profit margin[a] 1981	1980	FIRST-HALF 1981 Sales ($ millions)	Earnings	Change from 1980 Sales
Exxon	8%	$27,469.0	$1825.0	5%	77%	6.6%	3.9%	$57,792.0	$3425.0	7%
Mobil[b]	4	16,565.0	700.0	8	2	4.2	4.5	33,709.0	1340.0	10
Texaco[b]	3	14,799.0	555.7	18	10	3.8	4.0	30,258.4	1213.7	17
Standard Oil of California	3	10,979.0	616.0	3	15	5.6	5.0	22,967.0	1282.0	9
Standard Oil (Ind.)	11	8,139.2	552.8	13	13	6.8	6.8	15,992.3	929.5	17
Gulf Oil	10	7,200.0	311.0	6	−34	4.3	6.9	15,074.0	614.0	4
Atlantic Richfield	8	6,968.0	380.1	23	−13	5.5	7.7	14,100.4	726.6	27
Shell Oil	16	5,554.0	410.0	13	1	7.4	8.3	10,967.0	771.0	13
Conoco	5	4,900.0	158.7	4	−36	3.2	5.3	10,300.0	409.6	14
Phillips Petroleum	14	4,070.0	229.8	26	7	5.7	6.7	8,300.0	500.6	26
Sun Co.[b]	3	3,900.0	163.0	30	−33	4.2	8.2	7,900.0	283.0	30
Tenneco	12	3,776.0	203.0	18	9	5.4	5.8	7,585.0	397.0	16
Getty Oil	2	3,216.5	205.0	22	−16	6.4	9.2	6,511.2	435.2	33
Occidental Petroleum	21	3,127.9	128.2	4	−20	4.1	5.4	6,507.5	387.6	3
Standard Oil (Ohio)	4	2,907.9	478.7	2	6	16.5	15.9	6,027.2	999.1	10
Union Oil[b]	10	2,775.8	183.5	1	−6	6.6	7.1	5,442.3	338.0	6
Ashland Oil	14	2,456.0	13.3	19	−71	0.5	2.3	4,607.3	20.5	14
Cities Service[b]	7	2,265.3	77.5	23	−28	3.4	5.8	4,564.5	135.2	13
El Paso	14	1,007.0	37.8	12	62	3.8	2.6	2,008.0	68.7	16
Kerr-McGee	14	890.8	51.4	4	4	5.8	5.8	1,806.9	94.8	11

[a] After-tax income as percentage of sales. [b] Excludes major nonrecurring earnings: Mobil—$459 million first-quarter 1980; Texaco—$402 million in first-quarter 1980; Sun—$135 million in second-quarter 1981; Union Oil—$24.4 million in second-quarter 1981; Cities Service—$13.0 million in second-quarter 1981.

Petrochemical earnings are still down

If overall chemical earnings are finally beginning to pull up, petrochemical earnings at oil and natural gas companies are doing their usual thing in lagging behind. The best that can be said is that petrochemicals didn't do as badly as in the previous three quarters. At a few of the better-performing petrochemical operations, the second quarter brought signs of a turnaround. But for most firms, news from their chemical units was not good.

For six major U.S. oil companies supplying after-tax data, petrochemical earnings fell 18% in the second quarter from a year ago. This is less of a drop than the 55% decline for these companies in the first quarter (C&EN, May 11, page 17). As a result, first-half 1981 earnings for the group were down 38% from first-half 1980.

As in first-quarter reports, a large number of companies had things to say about chemical performance. Some comments have turned hopeful, but most are still negative. Shell Oil president John F. Bookout could be speaking for many other companies when he says, "We have not seen the turnaround in chemical product results which we had expected by this time. Significant improvement in this sector is highly dependent on the economy, particularly automobiles and housing, and we remain hopeful that business conditions for chemical products will improve later in the year."

At Exxon, the largest petrochemical producer, chairman C. C. Garvin Jr. fills in a few numbers behind the company's continuing profits drop. Although dollar sales in the first half of 1981 gained 3% from a year ago, physical sales volume was down 5% worldwide. Profit margins were lower for most product lines, influenced by a combination of excess plant capacity and rising costs.

Some chemical units at oil companies are still in the red. For example, Conoco sustained a $1.2 million loss in the second quarter in contrast to an $18.2 million profit a year ago. For the first half, Conoco had a $3.8 million loss compared to a $43.7 million profit in 1980. The problem is caused by higher feedstock costs, sharply lower physical sales volume for petrochemicals, and competitive price pressures in plastics.

However, a few chemical operations in the oil industry turned in profit gains in the second quarter amid general optimism from management. For example, Standard Oil (Ind.) registered an after-tax profit pickup in chemicals of 12% in the second quarter from a year ago. Chairman John E. Swearingen comments that prices in most chemical lines have remained strong enough to preserve profit margins despite declining demand in some lines.

AFTER-TAX EARNINGS

$ millions	Second quarter 1981	1980	% change	First half 1981	1980	% change
Conoco	$ −1.2	$ 18.2	Deficit	$ −3.8	$ 43.7	Deficit
Exxon	96.0	107.0	−10%	157.0	269.0	−42%
Mobil	27.0	26.0	3	53.0	62.0	−14
Shell Oil	15.0	54.0	−72	21.0	77.0	−73
Standard Oil (Ind.)	51.7	46.1	12	91.1	105.3	−14
Texaco	26.3	9.1	190	48.7	39.2	24
TOTAL	$214.8	$260.4	−18%	$367.0	$596.2	−38%

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FIRST-HALF 1981			STOCK MARKET DATA							
Change from 1980	Profit margin[a]		Earnings per share		Stock price			Price-earnings ratio	Annual indicated	Dividend yield, %
				Recent		Recent 12 months			dividend	of price
Earnings	1981	1980	2nd qtr	12 months	July 31	High	Low	July 31		
16%	5.9%	5.5%	$2.11	$7.08	35	44 3/8	32 3/8	5	$3.00	8.6
−13	4.0	5.0	1.65	6.18	30 5/8	44 1/4	27 1/4	5	2.00	6.5
10	4.0	4.3	2.09	8.77	36 1/4	54 3/8	33 1/8	4	2.80	7.7
10	5.6	5.5	1.80	7.49	42 1/2	51 3/4	35 1/8	6	2.40	5.6
−13	5.8	7.8	1.90	6.10	60 3/8	99 1/2	49	10	2.60	4.3
−29	4.1	5.9	1.59	5.44	39 1/4	52 3/4	30 5/8	7	2.80	7.1
−16	5.2	7.8	1.51	5.61	50	74 3/8	40 3/4	9	2.20	4.4
−1	7.0	8.1	1.33	4.96	45 3/4	65 1/2	34	9	1.80	3.9
−29	4.0	6.4	1.54	8.02	91 1/4	91 1/4	47 1/2	11	2.60	2.8
0	6.0	7.6	1.51	7.04	43 1/2	62 7/8	34 1/4	6	2.20	5.1
−43	3.6	8.2	1.30	4.50	40 1/8	59 5/8	31 1/4	9	2.10	5.2
9	5.2	5.6	1.50	5.82	39	58 3/8	36 3/4	7	2.60	6.7
−7	6.7	9.6	2.49	10.19	72 7/8	108 1/4	59	7	2.40	3.3
−12	6.0	6.9	1.47	7.59	27 3/8	39 1/8	24 3/4	4	2.50	9.1
11	16.6	16.4	1.94	7.74	51	91 1/2	42 3/8	7	2.40	4.7
4	6.2	6.0	1.06	3.68	41 1/4	56 1/2	28	11	0.80	1.9
−78	0.4	2.3	0.14	2.93	36	45 3/4	29 1/8	12	2.40	6.7
−51	3.0	6.9	0.93	4.02	54	62 1/4	31 1/4	13	1.60	3.0
30	3.4	3.1	0.79	2.61	26 3/8	29 1/2	19 1/4	10	1.48	5.6
−2	5.3	5.9	1.96	6.94	77 1/2	93	61 1/2	11	2.00	2.6

average of 6.2% from 7.0% for the first half of 1980.

For the 20 larger companies, sales increased 10% over last year's first half to $46.59 billion. Earnings increased 7% to $2.77 billion. Profit margins at the 20 larger companies fell slightly to 5.9% in the first half of 1981 from 6.1% last year.

The smaller companies on the list fared worse, however. While sales were increasing 15% to $5.62 billion, earnings were falling. The 5% increase in earnings in the second quarter was not enough to pull the year-to-year change for the 20 smaller companies into the positive numbers after a 12% decline in the first quarter.

Earnings for this group in the first half were off 9% to almost $493 million. The result is a drop in profit margin to 9.0% in the first half of this year from 11.1% in the first six months of last year.

On the plus side, fibers continued the improvement that they started the fourth quarter of 1980. At Allied Corp. sales and income from nylon carpet fiber operations were substantially higher than in last year's second quarter.

At Du Pont, fiber net income was $93 million in the second quarter, up 186% over the $32 million in net income for fibers in the second quarter last year. Fibers contributed 35% of the company's earnings in the second three-month period this year. Fiber sales (worldwide) at Du Pont were $1.31 billion, an increase of 20% from second-quarter 1980.

Monsanto's fiber operations improved in the second quarter from a year ago, although they were not so good as they had been in the first quarter this year. Monsanto's fiber sales in the second quarter increased 11.2% from a year ago to $276.2 million.

Fiber operating income in this year's second quarter was $7.2 million, better by any standards than the $41.4 million loss Monsanto suffered in the second quarter of 1980. However, the $7.2 million operating income was 58% lower than in this year's first quarter.

For the half, Monsanto fiber sales were $547 million, a 9.3% gain from the first half of 1980. Operating income for the half was $24.5 million, compared with a loss of $71.1 million in the first half a year ago.

At Celanese, fibers also performed well on a year-to-year basis, and unlike Monsanto, income from fibers in the second quarter showed good improvement over that of the first.

Fiber income at Celanese in the second quarter was $1.15 per share, an increase of 161% from second-quarter 1980. And the $1.15 per share was 69% ahead of fiber earnings in the first quarter this year.

Much of the improvement at Celanese was contributed by polyester, earnings from which in the second quarter amounted to 35 cents a share compared to a loss of 8 cents a share in the second quarter a year ago.

For the first half, Celanese fiber earnings were $1.18 per share, an increase of 118% over last year's first half. Again, polyester added to this; earnings from those operations in the first half improved to 42 cents a share from a loss of 17 cents a share in the first six months last year.

While earnings were improving in fibers, some other areas were not so fortunate. One of these in particular was phosphate fertilizers. At Williams Cos., Joseph H. Williams, chairman and chief executive officer says, "Agrico Chemical Co.'s nitrogen product prices and margins were good throughout the second quarter. However, phosphate product prices and margins declined as inventories increased. We are now curtailing phosphate production at two of our plants, which will adversely affect results for the third quarter and the year."

Freeport-McMoRan says that

Earnings also improve at most diversified chemical producers

	% Chemical sales	SECOND-QUARTER 1981 Sales ($ millions)	Earnings	Change from 1980 Sales	Earnings	Profit margin[a] 1981	1980	FIRST-HALF 1981 Sales ($ millions)	Earnings	Change from 1980 Sales
General Electric	4%	$6950.0	$436.0	12%	8%	6.5%	6.5%	$13,040.0	$795.0	8%
U.S. Steel	12	3792.0	167.6	20	50	4.4	3.5	7,191.4	438.5	14
Dart & Kraft	11	2608.2	116.1	16	16	4.5	4.5	5,010.3	212.6	10
Eastman Kodak	23	2417.4	284.5	13	19	11.8	11.3	4,722.7	533.6	11
3M	15	1664.0	135.0	10	−14	8.1	10.4	3,246.0	277.7	8
Georgia-Pacific	13	1443.0	55.0	21	0	3.8	4.6	2,791.0	107.0	15
Aluminum Co. of America	10	1304.6	81.5	1	−45	6.3	11.5	2,603.6	182.6	0
Borden	34	1208.6	40.2	−5	2	3.3	3.1	2,261.5	72.4	−4
Northwest Industries	7	926.9	67.1	35	112	7.2	4.6	1,736.9	118.7	29
FMC	35	911.5	42.0	4	7	4.6	4.5	1,797.7	83.4	3
Kaiser Aluminum	13	893.6	68.5	−11	−17	7.7	8.2	1,728.0	136.6	−5
Martin Marietta	10	880.2	61.1	37	4	6.9	9.1	1,597.7	100.8	32
Esmark	26	848.1	29.7	17	62	3.5	2.5	1,582.0	41.3	17
Pfizer	14	810.3	74.8	14	15	9.2	9.2	1,608.1	139.5	11
Merck	16	744.3	108.5	10	−2	14.6	16.4	1,469.6	220.3	11
Borg-Warner	24	712.3	42.0	6	33	5.9	4.7	1,388.3	76.6	3
NL Industries	26	687.2	75.4	35	90	11.0	7.8	1,292.9	135.0	27
General Tire & Rubber[b]	19	658.2	22.7	24	229	3.5	1.3	1,226.7	29.2	18
Uniroyal	27	626.4	22.7	6	[c]	3.6	[c]	1,167.9	30.3	0
Eli Lilly	20	624.6	76.7	4	3	12.3	12.4	1,437.2	201.5	9
Koppers	30	538.4	16.1	16	−18	3.0	4.2	964.3	12.4	11
Upjohn	19	513.9	40.0	16	−13	7.8	10.3	995.4	92.2	14
National Distillers	36	522.3	34.5	4	18	6.6	5.9	1,030.9	68.8	−2
Emhart[b]	16	442.8	17.0	−3	1	3.9	3.7	876.4	21.4	−3
Engelhard[b]	7	433.3	20.6	−29	24	4.8	2.7	1,138.3	35.7	−31
Cabot	31	417.3	29.5	19	29	7.1	6.5	826.4	60.3	9
Vulcan Materials	38	205.2	23.1	9	18	11.3	10.3	373.2	37.2	4
Big Three Industries	30	200.0	26.3	30	29	13.2	13.2	398.7	52.4	30
Ferro	15	189.3	5.1	11	10	2.7	2.8	368.5	9.6	8
GAF	44	174.1	4.3	9	191	2.8	0.9	350.8	7.4	9

a After-tax earnings as percentage of sales. b Excludes major nonrecurring earnings: General Tire—$4.4 million charge in first-quarter 1981; Emhart—$3.9 million in second-quarter 1980; Engelhard—$5.2 million in second-quarter 1981. c Deficit in 1980. na = not available.

phosphate markets in the U.S. and abroad weakened late in the first half. The combined fallout effects of some overproduction and a strong U.S. dollar, high interest rates, and weaker grain prices which curtailed farmers' net income and ability to finance and buy the anticipated level of fertilizer product, created some excess inventory. Phosphate fertilizer prices have declined to generally unprofitable levels for most manufacturers.

Many of the chemical companies attributed their improved earnings to increased volume and better pricing in U.S. markets. For instance, industry leader Du Pont says that net income from U.S. operations in the second quarter was $220 million, a 121% increase over the second quarter last year. The improvement, the company says, was due primarily to higher volume, moderation in the rate of increase in the price of raw materials and energy, and increases in selling prices.

Although many companies were saying nice things about the U.S. chemical business, more found problems in foreign operations. It is as if companies are saying that although business was good, it should have been better. Chief among the overseas problems were soft economies and the strengthening dollar against other currencies.

Again, Du Pont sounded the theme for many of the companies. Net income from foreign operations at Du Pont was down 44% to $42 million in the second quarter. The company says that international operations were affected by the recession in Europe, economic weakness in Brazil and Argentina, and strengthening of the dollar against world currencies.

Dow Chemical's financial vice president Robert M. Keil, however, says that he had observed an upturn during the spring in economic conditions in most of the countries in which Dow operates. But, he says, business in the Far East was slow in the countries that depend on exports to the U.S. Air Products also noted a continuing slowness in the European economies. But, in the foreign area, it seems to be the strengthening dollar that is giving chemical companies the most trouble. Hercules chairman Alexander F. Giacco says that "continued strengthening of the dollar reduced the foreign earnings contribution by approximately 18 cents a share."

Non-U.S. chemical operations also

FIRST-HALF 1981			STOCK MARKET DATA							
Change from 1980 Earnings	Profit margin[a] 1981	Profit margin[a] 1980	Earnings per share July 31	Earnings per share Recent 12 months	Stock price July 31	Stock price Recent 12 months High	Stock price Recent 12 months Low	Price-earnings ratio July 31	Annual indicated dividend	Dividend yield, % of price
7%	6.1%	6.2%	$1.92	$6.87	61	69 7/8	51 1/2	9	3.20	5.2
85	6.1	3.8	1.89	8.06	31 1/4	35 1/4	21	4	2.00	6.4
5	4.2	4.4	2.12	7.22	49 3/4	52 1/8	39 3/4	7	3.40	6.8
23	11.3	10.1	1.77	7.78	74 3/4	85 3/8	59 1/4	10	3.00	4.0
−14	8.6	10.8	1.15	5.38	54 1/4	65	50 3/8	10	3.00	5.5
2	3.8	4.3	0.51	2.29	24 3/4	32 3/8	22 1/2	11	1.20	4.8
−38	7.0	11.3	1.09	4.78	28 1/4	37 1/2	26 3/4	6	1.80	6.4
3	3.2	3.0	1.30	4.99	28 3/8	30	23 7/8	6	2.05	7.2
91	6.8	4.6	2.18	6.88	47 5/8	54 5/8	29 3/4	7	2.68	5.6
4	4.6	4.6	1.16	4.03	31	35 3/4	24	8	1.60	5.2
−12	7.9	8.5	1.54	5.16	20 7/8	30 1/4	19 7/8	4	1.40	6.7
8	6.3	7.7	2.45	7.84	59 3/4	76 3/4	51 3/4	8	2.88	4.8
61	2.6	1.9	2.23	4.91	53	55	24	11	1.84	3.5
14	8.7	8.5	1.00	3.66	47	54 7/8	39 3/4	13	1.60	3.4
4	15.0	15.9	1.46	5.68	92 1/4	103	73 1/8	16	2.60	2.8
14	5.5	5.0	1.95	6.25	49 1/2	53 7/8	37 1/4	8	2.48	5.0
77	10.4	7.5	1.12	3.36	42 1/8	42 5/8	24 1/8	13	0.80	1.9
[c]	2.4	[c]	0.93	3.08	26 5/8	29 1/2	16 5/8	9	1.50	5.6
[c]	2.6	[c]	0.81	0.37	9 1/8	10 3/8	4 1/8	25	0	0
9	14.0	14.1	1.00	4.72	54 7/8	68 3/4	48 7/8	12	2.30	4.2
−37	1.3	2.3	0.51	1.61	22 5/8	35 1/4	20 3/4	14	1.40	6.2
−4	9.3	11.0	1.33	5.55	55 1/2	69	51 3/4	10	2.00	3.6
−5	6.7	6.9	1.00	3.90	25 1/8	33 3/8	24 3/8	6	2.20	8.8
−41	2.4	4.0	1.38	3.85	32 1/2	37 1/2	28	8	2.40	7.4
7	3.1	2.0	0.76	na	19	30 3/4	18 1/2	na	0.56	2.9
17	7.3	6.9	0.93	3.35	33 5/8	36 3/8	25 1/2	10	0.92	2.7
26	9.6	8.2	2.00	6.72	47 3/8	56	36 1/2	7	2.20	4.6
29	13.1	13.3	0.62	2.33	32 1/4	38	25	14	0.60	1.9
−18	2.6	3.5	0.67	3.49	28 7/8	30 1/2	20	8	1.20	4.2
−8	2.1	2.5	0.25	0.44	14 1/4	16 3/8	9 1/4	32	0.80	5.6

hurt profits at a number of the more diversified U.S. chemical producers. Among those noting chemical profits damage from abroad are GAF, Emhart, National Distillers, and NL Industries. The chief causes are the same as for basic chemical companies' foreign troubles—poor European markets, especially in durables, and the stronger U.S. dollar.

Given these problems and the stagnant character of much of the U.S. economy, the wonder in the second quarter is that many diversified chemical producers did fairly well. One of the main reasons is good performance in agricultural chemicals, in which nonbasic chemical producers have a big stake. Companies reporting better profits in agchems include Esmark, FMC, Northwest Industries (Velsicol), and Uniroyal. Uniroyal, a considerably improved company after some blood-letting in the past two years, says that agricultural chemicals are its fastest-growing and most profitable product line.

However, agricultural chemicals gave problems to a few producers. Kaiser Aluminum & Chemical says that its agricultural chemical results declined from 1980 because of poor weather conditions in several key market states. And Eli Lilly encountered an interruption in growth of its highly successful Treflan herbicide. U.S. sales declined slightly in the first half from a year ago, but the main trouble was in Canada, where sales were crimped because of reduced acreage for rapeseed.

As usual, another product area, specialties, levered up profits for many diversified chemical producers—for example, General Electric's engineering plastics and Martin Marietta's specialty chemicals.

Problems remain for diversified companies making the bulkier basic chemicals. For example, at fast-expanding Georgia-Pacific, the chemical business improved overall in the second quarter from a year ago. However, chairman Robert E. Floweree notes that chemicals associated with the company's important polyvinyl chloride and phenol products were weak because of their close tie to the troubled construction industry. And at U.S. Steel, chemical operations, heavy in organic intermediates and commodity plastics, were hit by continuing depressed markets, which hurt volume and worsened a cost-price squeeze. □

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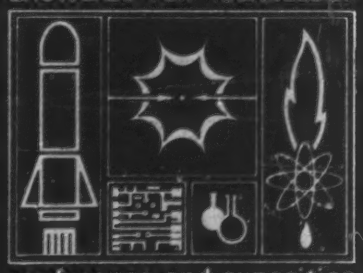

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Canadian chemical sales up, but earnings mixed in first half

The bare-bones, first-half sales and earnings figures for Canada's four largest publicly reporting chemical companies are like photographs without captions. It's not entirely clear what you are looking at.

True, all four companies reported higher sales in the first half of 1981, compared to last year's first half. It's also true that three of them—C-I-L Inc., Celanese Canada, and Du Pont Canada—sported higher earnings as well. On the other hand, Union Carbide Canada's first-half earnings were down a disappointing 37.5%.

Where does that leave the Canadian chemical industry in general? Probably not as badly off as Union Carbide nor as well off as the others' figures seem to indicate.

Like last year, 1981 is shaping up as a cyclical year—up one moment and down the next. Uncertainty—over constitutional issues, energy policy, and the strength (or lack of it) of the Canadian dollar—clouds the Canadian economic landscape.

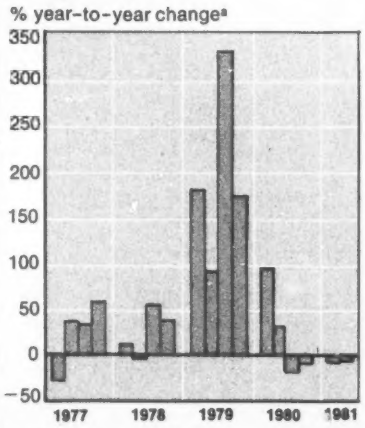
The one unwelcome constant is inflation. Factor inflation out of those sales and earnings gains and they become less attractive than they appear on first reading.

The Canadian dollar is a paradox. Against the U.S. dollar, it has slumped recently to its lowest level in 50 years. This should encourage exports of Canadian chemicals to the U.S. On the other hand, it makes imports of capital equipment for the industry's well-publicized expansion more expensive. Much of that equipment comes from the U.S.

Meanwhile, that same Canadian dollar that is depreciating against the U.S. dollar is appreciating against some major European currencies. Although not as large as the U.S., Europe also is a major export market for Canadian chemicals. But now the currency situation makes it more difficult and less profitable to sell there.

The other factor having a large and negative impact on Canadian chemical company profits is energy costs. Although the debate over national energy policy is far from over, energy and feedstock costs have risen dramatically in Canada. This much is made painfully clear in the earnings statements of all four of the large publicly reporting Canadian chemical companies.

Combined earnings trail last year's level



a After-tax earnings of four largest publicly reporting Canadian chemical companies—Celanese Canada, C-I-L, Du Pont of Canada, and Union Carbide of Canada.

Three of big four Canadian firms improve earnings

$ Millions (Canadian)	FIRST SIX MONTHS, 1981 Net Sales	Change from 1980	Net Income	Change from 1980	Profit margin[a] 1981	Profit margin[a] 1980
C-I-L Inc.	$ 615.8	20.7%	$ 33.5	15.5%	5.4%	5.7%
Celanese Canada	219.5	10.0	12.3	15.5	5.6	5.4
Du Pont Canada	596.3	23.6	28.4	8.4	4.8	5.4
Union Carbide Canada	419.7	9.3	26.8	−37.5	6.4	11.2
Total	$1851.3	17.5%	$101.0	−7.1%	5.5%	6.9%

a Net income as percentage of sales.

C-I-L chairman and chief executive officer W. J. Mandry notes, for instance, that growth of his company's operating income was "moderated" by a substantial increase in the costs of natural gas feedstock, ethylene, and phosphate rock. Yet C-I-L was able to increase first-half sales to almost $616 million, 20.7% better than last year, thanks primarily to improved sales of agricultural chemicals, industrial chemicals, explosives, mining equipment, and chemical process technology. C-I-L's net income rose 15.5% to $33.5 million, but its profit margin declined.

A strong export performance helped Du Pont increase first-half sales by 23.6% to about $596 million. Export sales topped $53 million and shipments of nylon products to the carpet industry were up significantly. However, these gains were offset by lower earnings in plastics and films, which had higher feedstock costs that couldn't be recovered by higher prices.

Union Carbide blames a worldwide oversupply of petrochemicals for poor chemicals and plastics export business. Although business in Canada remained strong during the first half, import competition made it impossible to raise prices enough to offset increased feedstock costs.

Despite improvements in sales of gases, metals, and carbon products, Union Carbide's net income dropped 37.5% to $26.8 million.

Record sales in the second quarter pushed Celanese's first-half sales to nearly $220 million; star performers were polyester and polypropylene.

Although Celanese's net income rose 15.5% in the first half, it could have been better had it not been for energy costs. The company spent $3 million more for energy in the first half of 1981 than it did in the first six months of 1980.

The uncertainties that plague the Canadian economy make it difficult to predict how Canadian chemical companies will fare during the second half of the year. C-I-L's Mandry notes, for instance, that although first-half results were better than they were in 1980, labor unrest in industries important to the companies, steadily increasing costs of energy-based raw materials, and high interest rates will make it "difficult to continue."

A Du Pont representative cites rapidly rising costs and a highly competitive environment as causes for the uncertain outlook for the remainder of the year.

Earl Anderson, New York

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Chemical & Engineering NEWS

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SYNTHETIC FUELS

Signs of progress mask industry problems Page 13

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Chemical & Engineering NEWS

Cover: Ashland Synthetic Fuels H-Coal pilot plant at Catlettsburg, Ky. Photo courtesy of Ashland Oil

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- ***Du Pont shareholders approve Conoco merger*** *overwhelmingly—the largest U.S. merger ever.* ***Page 5***
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News Feature

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Synfuels progress likely to remain slow

Administration's decision to support three commercial-scale projects will spur development of young industry, but falling oil prices and budget cuts at Department of Energy are problems

David J. Hanson
C&EN, Washington

Large-scale production of synthetic fuels, primarily conversion of oil shale and coal to liquids and gases, is nearer reality today than it has been at any other time since the decline of the old coal gas industry. President Ronald Reagan's decision to permit government support of three large, commercial-scale projects in recent weeks has ended an anxious period for the fledgling synfuels industry and opened the door for private support of even more projects.

However, the industry still faces problems. The Administration's budget cuts have taken away much of the Department of Energy's funds for cooperative agreements and feasibility studies for new projects. The price of imported crude oil is falling and oil is in oversupply on world markets. Even without lower oil prices, no one is sure how economical a synthetic fuel plant will be, and how competitive will be its products. So, while active supporters of the synfuels industry are bullish on its prospects, progress likely will continue to be slow.

That the nation needs a large synfuels industry is not disputed by many, although some criticize present programs. The U.S. has built its economy on the availability of cheap and plentiful energy, and continued growth of the nation is dependent on continued growth of its energy supply.

That is easy to say and has become something of a truism. But the problem is that traditional sources of energy—petroleum and natural gas—are not as abundantly available as they once were. Domestic supplies of crude oil are not adequate for U.S. needs, and supplies of natural gas, although recently rising slightly, are expected to peak in a few years. Imported petroleum is affordable and presently available in sufficient supply, but this source cannot be relied on indefinitely both for political reasons and the obvious eventuality that these supplies will someday run so low that they will become too expensive for use as motor fuel, or possibly even as chemical feedstock.

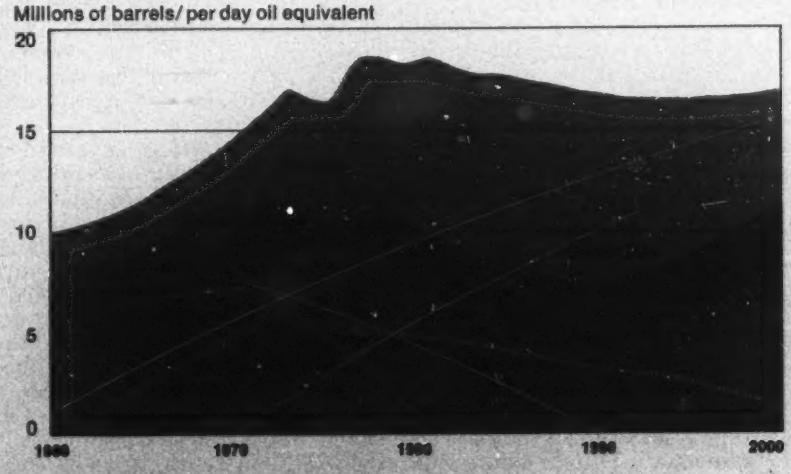
Conversion of coal to other, more usable, fuels is an old idea. Coal gas, formed by heating bituminous coal with steam, was used to light towns in the early 19th century. Distilled tars from this process were used as motor fuels following World War I, and the first U.S. patent for converting coal to a heavy crude oil was filed in 1914. Congress has passed legislation three times to get a coal-based synthetic fuel industry started. But each time it was diverted from its goal by the discovery of huge crude oil deposits. Today Congress seems intent on making sure that such diversions do not happen this time.

The Arab oil embargo of 1973–74 generated a lot of heat but little light on improving the nation's energy security. Even in 1975, when President Ford in his state of the union address called for legislation to form a synthetic fuels industry, Congress rejected the idea. It took another bout of long lines of angry motorists at gasoline stations in 1979 to get the legislators serious. What resulted was the Energy Security Act, which created the Synthetic Fuels Corp. (SFC) and set national goals for production of the equivalent of 500,000 bbl of oil per day of synfuels by 1987 and the equivalent of 2 million bbl per day by 1992.

President Carter signed that bill June 30, 1980, but after more than a year, progress toward development of a synthetic fuels industry is just barely creeping. Budget issues, Administration changes, and even the marketplace have served to hold up synfuels progress.

But Congress has kept on pushing. House majority leader James C. Wright Jr. (D.-Tex.) has addressed his colleagues so often about the need for more progress in awakening what he calls the "sleeping giant" of synfuels that it has become an inside joke at House subcommittee hearings. Sen. Henry M. Jackson (D.-Wash.)

U.S. oil supply won't rely on synthetics until after 1990



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Major synthetic fuels projects that are worth watching

Project and location	Principal sponsors	Process	Products	Feed	Status
Great Plains Gasification, Mercer County, N.D.	American Natural Resources, Peoples Energy, Tenneco	Lurgi-dry ash	125 million cu ft high-Btu gas per day; ammonia	14,000 tons per day coal	Received $2 billion DOE loan guarantee; on stream 1984
Memphis Industrial Coal Gasification, Memphis, Tenn.	City of Memphis	U-gas	150 million cu ft per day medium-Btu gas	3000 tons per day coal	DOE support halted; awaiting SFC loan guarantee
Colony Shale Oil, Grand Junction, Colo.	Exxon, Tosco	Surface retort	47,000 bbl per day oil	66,000 tons per day oil shale	Exxon financing 60%, Tosco has $1.1 billion DOE loan guarantee; on stream 1986
Union Oil Shale, Parachute Creek, Colo.	Union Oil Co.	Upflow retort modules	10,000 bbl per day oil	12,500 tons per day oil shale	Has purchase agreement, price support from DOE; on stream 1983
H-Coal Liquefaction Process, Cattletsburg, Ky.	Ashland Synthetic Fuels	H-Coal	650 bbl per day liquid fuels	220 tons per day coal	Pilot plant on stream with DOE support through 1982; applied for SFC support
Exxon Donor Solvent Liquefaction, Baytown, Tex.	Exxon, Electric Power Research Institute	Exxon Donor Solvent	600 bbl per day liquid fuels	250 tons per day coal	Pilot plant on stream
Chemicals from Coal, Kingsport, Tenn.	Tennessee Eastman	Texaco, Scientific Design	Acetic anhydride, sulfuric acid, methanol	1600 tons per day coal	On stream 1983

took to the Senate floor last month in exasperation over the continuing delays in action. "Years from now we rightly will be considered fools if we continue to do nothing to break the pattern of this cycle" of fuel interruptions and steep price increases, Jackson said.

President Reagan finally has approved the use of federal loan guarantees and price supports for three synfuels projects. These are projects that had been the subject of negotiation with the Department of Energy for support before SFC was formed, under amendments to the Defense Production Act, a stop-gap measure enacted by Congress to be used until SFC was organized.

As a result of Reagan's decision, the first commercial-size synfuels plant to be built in the U.S. most likely will be a shale oil facility operated by Union Oil Co. The project site is near the town of Parachute, Colo., in the oil shale-rich Piceance Basin. The agreement, negotiated under the Defense Production Act, calls for delivery of 3000 bbl per day of military aircraft turbine fuel and 7000 bbl per day of diesel fuel for the Defense Department. Union Oil expects to start producing 10,000 bbl per day by mid-1983, adding another 40,000 bbl per day of product by 1988.

The government support is in the form of a purchase agreement for the fuel. The price charged the Defense Department will be going market rate at the time of delivery, but, if that price is less than $42.50 (indexed for inflation), the Department of Energy will pay the difference, up to a total of $400,000. In any case, the price support agreement will not apply for more than seven years of the 10-year contract.

The second project to be backed by government funds is the Great Plains Coal Gasification project in Beulah, N.D., being put together by a consortium headed by American Natural Resources of Detroit. Planning and design of the facility has been underway since 1972, and the project sponsors tried to get federal loan guarantees for it in both 1975 and 1976. When a novel plan to have the project's customers "guarantee" the project's finances with their bill payments fell through, the Energy Department was approached for a loan guarantee. A $2.02 billion agreement was reached in May of this year, but the President did not approve the deal until July.

Delays in getting government support for the project came whisker close to causing its death. American Natural Resources had been spending $500,000 per day, by its reckoning, waiting for the DOE approval, and was running out of money. With Reagan's approval, construction can begin almost immediately on the plant, which eventually will produce about 125 million cu ft per day of high-Btu gas using a Lurgi gasifier similar to the type used commercially by SASOL in South Africa (C&EN, Sept. 17, 1979, page 13).

The third approved project to be getting started soon is a joint venture between Tosco Inc. and Exxon to build an oil shale facility in the Piceance Basin near the site of the Union Oil plant. Exxon is financing its 60% share of the project on its own, but Tosco sought, and received, a $1.1 billion loan guarantee from DOE. The government hesitated to support this project because of the possibility that Exxon might handle all of the financing if DOE would not guarantee loans for Tosco, but the government decided to finance it anyway. The project is expected to cost about $3 billion and to produce 47,000 bbl of oil per day by the late 1980's.

It was a struggle to get these projects approved, even though conceivably they wouldn't cost the government any money. Feelings run strong in this Administration that federal support shouldn't go to sponsors ready to build commercial plants. They are expected to be able to compete in the marketplace with other fuels without government subsidies. The strongest spokesman for this position likely is David Stockman, director of the Office of Management & Budget, who has a history of antagonism to government assistance for energy projects. His stance has been opposed by Energy Secretary James B. Edwards, who, along with Congress, believes the government has an obligation to these projects, since they had been under way before the advent of SFC.

Still, the budget cuts and the marketplace philosophy have created

casualties. The most prominent of these may be the solvent-refined coal project, SRC-II, being managed by Gulf Oil subsidiary Pittsburg & Midway Coal Mining Co. An SRC-II pilot plant started operating in 1974 at Fort Lewis, Wash., and the wide range of end products and possible efficiency of this direct method for coal liquefaction made the project highly regarded. West Germany and Japan became cosponsors of SRC-II, paying 50% of the costs, the rest being borne by DOE. But enormous cost increases, from $492 million in 1979 to more than $1.2 billion in 1981, to build a large pilot plant gave project supporters pause. There were also some environmental concerns about the process. So this spring the project was disbanded, leaving Gulf to try to find other sponsors.

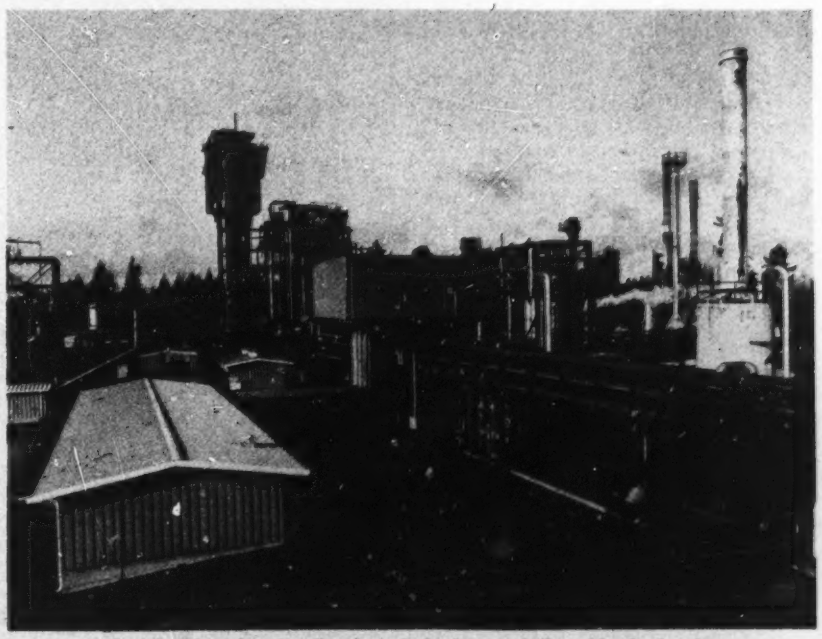
Other large projects that had been highly regarded during DOE negotiations but later were dropped include a large demonstration plant that was to be built by the Illinois Coal Gasification Group and a Lurgi gasifier demonstration project headed by Conoco Coal Co. In addition, hundreds of feasibility studies and cooperative agreements for everything from large synfuels complexes to small ethanol generators that were to be funded by DOE were eliminated as unnecessary or to save money.

These projects, and possibly others, were lost for two reasons, says Michael S. Koleda, executive director of the National Council of Synthetic Fuels Production, the year-old industry trade association: a change in the oil climate and a change in philosophy with the election of Ronald Reagan.

President Carter was shaping his energy policy, Koleda says, during a time of doubling oil prices, a revolution in Iran, and the nuclear reactor accident at Three Mile Island, which disrupted the possibilities for increased nuclear power. So Carter pushed for conversion of utilities to coal from oil and gas, and set up a mechanism for the long-term conversion of coal and oil shale to liquid fuels and gas.

When Reagan was elected to office, he found a different climate. "Oil was temporarily in abundance and the Organization of Petroleum Exporting Countries did not seem to have the control over its members it had a year earlier," Koleda says. "Prices of gasoline were moderating. In fact, in both real and absolute terms, they were declining."

Also, Reagan differs philosophically from Carter. Carter held that the federal government had the responsibility to provide energy security. Reagan, on the other hand, insists that if the government would back away from its regulations and deregulate prices, the private sector could provide adequate fuels. And, if we need to protect ourselves against the disruption of oil supplies, Koleda says, Reagan has the strategic petroleum reserve to fall back on.



Fort Lewis solvent-refined coal plant was victim of budget cuts

Koleda believes that the axed demonstration projects, cooperative agreements, and feasibility studies were as much victims of the Administration's attempt to cut the budget as of any conscious policy toward energy development. "Politically, I suspect, it is easier to get rid of the pilot plants and demonstration plants because you are getting rid of real outlays from the budget," Koleda says. "When you hack away at DOE you are fulfilling a political promise. When you go after [SFC], however, you are going after funny money, money that may never result in outlays. So there are no immediate budget victories, and you are dealing with a new program that has broad Congressional support."

There is now a void in the Energy Department's efforts to support fossil fuels development. DOE is to continue funding research and preliminary development work on new synthetic fuels technology, up to the construction and operation of small—about 200 tons of coal per day—pilot plants. But the more expensive demonstration plants, greatly needed to move the process up to a scale large enough that key items of equipment planned for commercial units can be tested, now are considered beyond DOE support. And current government attitudes are against SFC's financing them either, even though legislation setting up SFC has a provision that might permit it. There is some concern, then, that advanced, and possibly competitive, technologies such as the SRC-II project may never make it to commercial use in the U.S.

The future of large synfuels projects now sits squarely in the lap of SFC. But this corporation has not been moving very fast to get started. Although President Carter nominated John Sawhill chairman of SFC and filled the board of directors, none of these were ever confirmed by the Senate as required in the Energy Security Act. When Reagan came to office, all were fired, and he chose Edward E. Noble to be the corporation's chairman. Noble is presently the only board member confirmed by the Senate, although four of the six other members have been nominated by the President. The four candidates are Robert A. G. Monks of Boston Co., a financial holding firm; Victor Schroeder, an Atlanta real estate executive and friend of Noble; V. M. Thompson Jr., a banking executive from Tulsa; and C. Howard Wilkins, the Wichita, Kan., businessman who launched the Pizza Hut chain.

Now that Reagan has approved the three DOE synfuels projects, the

Senate may move soon to confirm the nominated board members so SFC can begin work. The corporation's staff already is evaluating the 63 proposals they received in their first solicitation and have sent each project sponsor a detailed questionnaire to try to get the technical and financial information they will need to make a decision on whether to support a project. Noble has told Congress that SFC can begin hard negotiations with sponsors within six months after the board of directors is approved.

But even then, no one is sure what projects might be chosen. It has been rumored that Noble has a preference for processes that produce liquid fuels and that he believes gasification projects produce gas that is too expensive for a time of adequate supply. Also, Noble is a businessman who believes in the strengths of the marketplace, and he maintains SFC will support only projects that are competitive in that marketplace.

In the complex economics that surround synthetic fuels, this presumably means that competitive projects are those which, at some time in the future, will produce products that are economically competitive with natural fuels. The first rule in these economics is that in time the price of petroleum will rise at least as fast as the rate of inflation.

Neil Eisner, acting finance officer at SFC, says this is significant because most of the costs of synfuels plants are embedded in the capital costs of constructing the plant, so the inflation rate of the synthetic products will be less than the inflation rate of natural products.

But normal sources of investment capital are not available to finance synfuels projects. There are still too many unknowns in the future to permit them to take the risk. What if the price of oil does not go up as believed? What if cost overruns and equipment problems cause projects to fail? What if unknown environmental problems cause plants to shut down?

"Until there are projects in the U.S. for institutional investors to see and to be able to project the reasonable operating factors for those projects, you won't see many of them done completely using other people's money as project financing," Eisner says. So SFC came in to take the risks for the investors until the industry proves its worth.

The risk-taking by SFC will certainly move the development of synfuels faster than leaving it to private financing. The corporation will support projects in several ways, de-

Noble: hard negotiations to begin soon

pending on what the sponsors ask for and other criteria. The primary method will be loan guarantees for up to 75% of the project cost, with a ceiling of $3 billion per project. With only $20 billion to use for support through 1984, however, SFC can't make many awards of this size. Once it backs a project, though, there should be no trouble getting the loans.

The second type of support will be price guarantees for products, allowing them to be sold in competition with other fuels. Agreements would permit taking into account actual prices and operatings costs, similar to the arrangement Union Oil has with DOE. Less likely forms of project support include purchase agreements in which SFC would buy all or part of a facility's output, direct loans to sponsors for up to 75% of an otherwise unfinanceable project, and joint ventures with companies to build project "modules" that could be used to scale up projects to commercial size—which may be the way SFC could be coaxed into supporting demonstration-size facilities.

SFC is going to have its hands full trying to determine if a project's products are going to be competitive and when. Several attempts made recently at comparing prices have given different answers, and none claims to be particularly accurate.

A report gaining some notoriety was prepared in March by Robert V. Jelinek of the State University of New York, Syracuse, for the House Subcommittee on Energy Development, chaired by Rep. Don Fuqua (D.-Fla.). The report's main conclusion is that the prices of products from synfuels plants will rise with the price of crude oil, so that, when built, no process will be able to make a product as cheap as the natural product. Jelinek predicts some very high prices for synfuels product but many other analysts say his assumption about the correlation between oil and synfuel prices is wrong.

More respected within the industry are estimates by the Engineering Societies Commission on Energy Inc. (C&EN, July 27, page 43) and by Bechtel, both of whom use, unfortunately, 1979 data. Their work shows that oil shale is the most economical way to go today, followed by coal liquefaction, coal gasification, and, most expensive, generation of fuel by biomass conversion (primarily ethanol from corn).

But SFC will make its own economic evaluation of each project, including sensitivity analysis of product price factors, Eisner says. Still, decisions on whether the project can be supported will have to wait for approval of a lengthy set of criteria by SFC's board of directors.

These criteria were proposed by John Sawhill and his staff in January and presently are being reviewed and revised following public comments. In addition to the financial capabilities of the project and its sponsors, the criteria will include the technological soundness of the facility, the labor situation, the socioeconomic impact on the proposed project site, water availability and quality, and environmental and regulatory acceptability.

The procedure will be complex, and probably slow, and no one at SFC is speculating which or even what kinds of projects, if any, are likely to get support from the corporation. If SFC carries out its mandate of supporting diverse technologies, as spelled out in the Energy Security Act, some projects seem to have better prospects than others.

One such project might be the gasification project sponsored by Memphis Light, Gas & Water Division. This project had been funded by DOE for years and is ready for commercial scale. It also has the most vigorous sponsors trying to get SFC support and apparently is the first to return the extensive data requested last month by SFC. It would produce 50 million cu ft per day of medium-Btu gas (equivalent to about 10,000 bbl of oil) to be used directly as an industrial fuel. It would use a fluidized bed gasifier technology not now in commercial use developed by the Institute of Gas Technology.

A second possibility is the liquefaction project being operated by

Synfuels' environmental problems are yet to be resolved

A very large stumbling block to development of a synthetic fuels industry, or even the construction and operation of the first commercial plant, is the issue of environment and health.

Large synfuels complexes will have to confront just about every environmental regulation on the books, from the Clean Water Act to the Toxic Substances Control Act. Industry spokesmen are confident that compliance can be achieved without much difficulty. But despite the ease with which some permits and licenses have been obtained, big questions remain.

The Environmental Protection Agency moved quickly after creation of the Synthetic Fuels Corp. to make sure SFC took proper environmental care over the projects it supports. Then-EPA Administrator Douglas M. Costle went to the SFC board of directors in January and promised a set of pollution control guidance documents for each of the major synfuel technologies—coal gasification, shale oil, and direct and indirect liquefacation. The idea, Costle said, is to build these plants right the first time.

The question is how to do this. No one knows yet just what pollutants will have to be controlled. Data on these processes and products are too scarce to make decisions. Most of the product information available is on shale oil and fuels from coal liquefaction pilot plants. Most testing of products has been done to determine their performance and handling characteristics, not their toxic constituents.

A primary concern about synfuels plants is water use. These big complexes will use millions of gallons of water daily, and much of that becomes wastewater that cannot simply be returned to a stream. Persons concerned with what already appear to be critical water shortages in the Western U.S. view the building of large shale oil plants there with alarm. Moreover, the process generates huge piles of spent shale that have the potential of leaching hazardous chemicals into underground aquifers. The U.S. Water Resource Council, however, estimates there is enough water in the upper Colorado region, where these plants will be built, to produce 3 million barrels of oil per day.

Compliance with the Clean Air Act will also be a problem. Emissions from synfuels plants include relatively large amounts of polycyclic aromatic hydrocarbons and heavy metals like arsenic, lead, and mercury, for which no EPA standards exist. Conventional pollutants such as nitrogen oxides, sulfur dioxide, and particulates will be controlled, but huge amounts of carbon dioxide also will be generated—causing enough concern for the Department of Energy to have asked the National Academy of Sciences to do a study on the possible effects of carbon dioxide from a large synfuels industry. The levels of air pollutants will have to be watched closely, too, because EPA's prevention of significant deterioration regulations are strict in the areas in which synfuels plants are being built.

Coal liquefaction, the technique used in methods such as the solvent-refined coal processes, appears to be a special problem. The high levels of potentially toxic compounds produced in these processes may make unacceptable fuels, both to the end user and to those making them. It generally is found that these fuels contain much higher levels of aromatics such as benzene and xylene than natural fuels, as well as more fuel-bound nitrogen.

The SFC is preparing criteria requiring all project sponsors to comply with applicable EPA regulations before the corporation will support a project. Yet some environmentalists believe this is not enough.

David D. Doniger of the Natural Resources Defense Council and Norman L. Dean of the National Wildlife Federation have been worrying about synfuel plant pollution for some time. "There are a hell of a lot of unknowns," Doniger says. "And to the extent that anything experimental is being done on these projects, it is all devoted to improving the basic process of converting coal or shale oil to fuel, and none of it seems to be going to improving pollution control technology."

And that is just what they would like to see. In testimony prepared for Congressional hearings, Dean calls for stiffening SFC criteria to include improving and upgrading existing pollution technology. He claims that SFC is obliged to do this under the Energy Security Act, which requires that SFC encourage development of new technologies as part of its efforts to meet synthetic fuel production goals. In addition, Dean calls for more study on the part of SFC to assure that companies will make an effort to build environmentally safe facilities and not just comply with what are seen as inadequate standards for this situation.

Ashland Synthetic Fuels and Airco Energy Co., using the H-Coal process. The plant would be called the Breckenridge project for its location in Breckenridge County, Kentucky. It would be built to produce 50,000 bbl per day of hydrocarbon liquids and liquid equivalents.

Ashland's H-Coal operation is now the largest synfuels operation in the U.S. The DOE-funded pilot plant in Catlettsburg, Ky., can run 200 tons of coal per day and product about 650 bbl per day of fuel. If liquid fuels are to be preferred by SFC, the H-Coal system is proven, even if it is more expensive than shale oil.

One oil shale project that is well into development and that also has requested support from SFC is the Cathedral Bluffs project sponsored jointly by Occidental Oil Shale and Tenneco Oil Shale Co. The Cathedral Bluffs site is also in the Piceance Basin area of Colorado. Production capacity would be 50,000 bbl per day by 1988 and 94,000 bbl per day by 1990 using 166,000 tons per day of oil shale. It is about the biggest project in the works.

Many of the projects mentioned could be producing fuels within the time limit established in the Energy Security Act to have 2 million bbl per day of synthetic fuels in production in 1992, but it is not likely that that goal will be met. Noble contends that "these goals probably cannot, and should not, be met solely by projects funded by the corporation." In other words, unless privately financed ventures begin, the goal is too high.

In addition, the government could consider other ways to encourage more private financing, besides the "corporate welfare" of loan guarantees and price supports. Methods such as accelerated depreciation, more rapid deregulation of natural gas prices, elimination of taxes on profits allocated to development of synthetic fuels, tax credits based on synfuels production, and a tax on imported fuels have all been suggested as ways to help.

That an effective synthetic fuels industry will develop in the U.S. is widely accepted. Too much depends on the U.S.'s having reliable energy sources to believe otherwise. But whether this new industry can get itself going before there is another oil embargo, another war, or another revolution may depend on how serious the government is now in extending a helping hand. □

work so far—namely, that the potential resource is too large to ignore. It's possible that enough private funding can be had to continue some exploratory work. But it would seem that sooner or later the federal government will have to make the major contribution.

Joseph Haggin, Chicago

Process taps energy of waste carbon monoxide

A 1976 survey indicated that as much as 24 million tons per year of dilute carbon monoxide was being flared at industrial locations in the U.S., most of it from steel mills and petroleum refineries. The energy equivalent was about 570 million cu ft per day of natural gas. There was no economical way to utilize this large potential source of heat.

Now a process has been tested that will convert the dilute carbon monoxide streams to methane and carbon dioxide. Called COthane, the process has been developed at Union Carbide's Tarrytown, N.Y., technical center. Carbide's Albert C. Frost described the process for the summer national meeting of the American Institute of Chemical Engineers in Detroit last week.

The COthane process evolved from the observation that carbon monoxide rapidly disproportionates on a nickel catalyst to carbon dioxide and active carbon. The active carbon further reacts to form equimolar quantities of methane and carbon dioxide. According to Frost, this observation was the basis for subsequent laboratory-scale process development unit tests of the two-step process.

In the first step, waste gas is pretreated and passed through a reactor containing a nickel or cobalt catalyst bed. At temperatures of 270 to 300 °C the following disproportionation occurs:

$$4CO \rightleftharpoons 2\,CO_2 + 2\,C$$

This reaction proceeds until the catalyst is loaded with the active carbon. The waste gas feed is then diverted to a second reactor that has been stripped of carbon. Low-pressure steam is then introduced into the first reactor where it reacts with the active carbon according to the reaction:

$$2\,C + 2H_2O \rightleftharpoons CH_4 + CO_2$$

Eventually the carbon is consumed and the roles of the reactors are reversed. Continued alternation of the reactors provides continuous operation. The net reaction is:

$$4\,CO + 2H_2O \rightleftharpoons CH_4 + 3\,CO_2$$

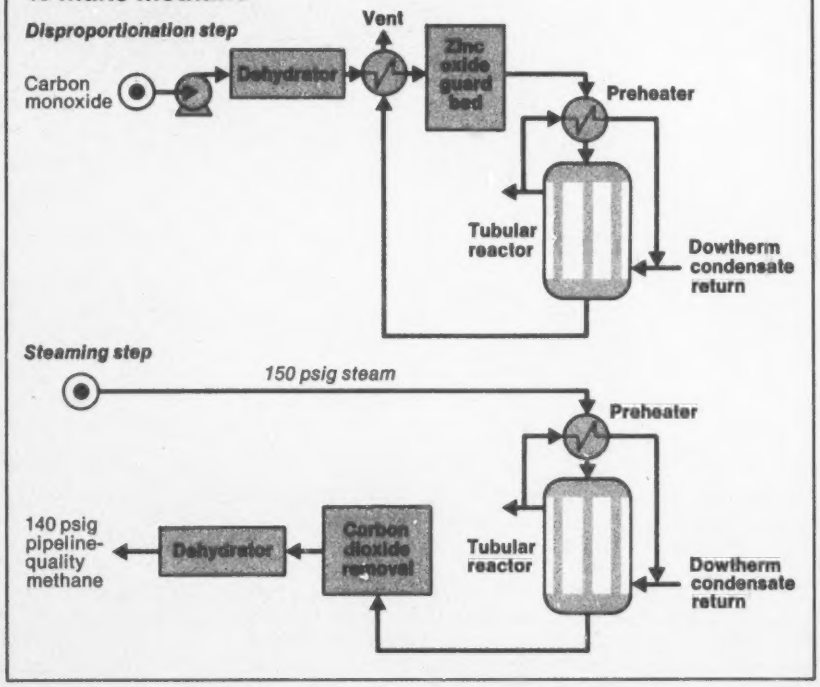
The wet carbon dioxide/methane stream is stripped of carbon dioxide and water, which are vented. The methane is fed to a local natural gas distribution system.

Feed pretreatment depends on the source of the carbon monoxide. Reactive diluents, such as oxygen, react with the active carbon and are undesirable. Catalyst poisons, such as hydrogen sulfide, are also removed. A small amount of "inactive" carbon appears to be deposited during each cycle and is purged periodically. About 79% of the gross energy available in the carbon monoxide appears in the product methane.

The largest single source of off-gas carbon monoxide is blast furnace exhaust, but this source is declining as antipollution measures are being implemented. However, the potential of the COthane process for upgrading exhaust from in-situ coal gasification could more than offset the decline in blast-furnace exhaust. Other major sources of carbon monoxide include basic oxygen furnaces, gray iron casting, aluminum production, and petroleum refining.

Methane production costs from blast-furnace exhaust have been estimated at $5.78 per million Btu; for BOF off-gas, $7.11 per million Btu; and for carbon-black off-gas $8.10 per million Btu. These costs are considerably higher than the price of natural gas, which presently is running at $2.00 to $4.00 per million Btu. However, Carbide believes that the cost gap will narrow with time and that the COthane process may be a good way to minimize losses associated with exhaust gas cleanup mandated by the Environmental Protection Agency. □

Two-step COthane process uses waste carbon monoxide to make methane



Energy industry to be major hydrogen user

An assessment of world hydrogen markets through the year 2025 has been completed by the International Energy Agency. Most of the consumption, it shows, will be for synfuels production and conventional chemicals production. IEA had been interested in promoting hydrogen as an energy carrier, but the economics don't favor development of this application for the period of the study, except in highly localized circumstances.

Contributing to the two-year study are mainly countries of Western Europe, North America, and Japan. A composite report was prepared from national estimates by a group headed

Study projects hydrogen consumption through 2025

Joules × 10^{18}	Belgium	Canada	Germany	Japan	Netherlands	Sweden	Switzerland	USA	Total
1985									
Nonenergy	20	107	136	100–110	65	5	1.8	730	1170
Energy									
Indirect	—	95	58	—	15	3–7	—	470	640
Direct	—	—	85	—	10	33	—	—	130
Subtotal	20	202	279	100–110	90	41–45	1.8	1200	1940
2005									
Nonenergy	20	140	220	130–170	65	6–14	1.8	1,600–2,000	2,400–2,900
Energy									
Indirect	40	200	940	—	180	4–22	—	4,600–5,200	6,000–6,600
Direct	—	4	260	90	20	41–130	14	900–1,500	1,200–2,000
Subtotal	60	344	1420	220–260	265	53–166	16	7,300–8,700	9,600–11,200
2025									
Nonenergy	20–40	180	260	190–270	—	18–25	1.8	3,000–4,000	3,700–4,800
Energy									
Indirect	40–50	340	1600	—	—	3–21	—	15,000–20,000	17,000–20,000
Direct	30	7	400	0–1100	—	68–230	58	2,400–4,200	3,000–6,000
Subtotal	90–120	520	2500	190–1300	—	89–280	60	20,000–28,000	24,000–33,000

Note: 1 Btu = 1054.6 Joules.

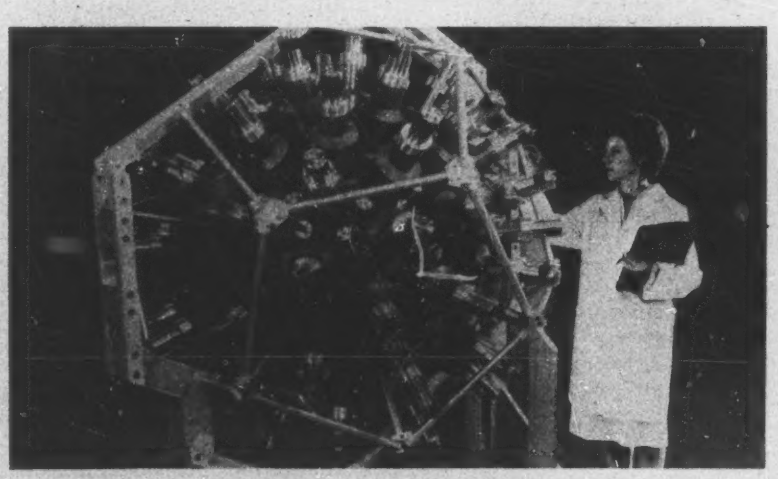
by Wim van Deelen of the Commission of European Communities. A summary of the study was presented last week in Detroit to the American Institute of Chemical Engineers by William J. D. Escher of Escher:Foster Technology Associates, St. Johns, Mich., who was a consultant for Jet Propulsion Laboratory, which represented the U.S. in the study.

Three major categories of consumption considered by the report are nonenergy uses, such as chemical reactants and metallurgical reductants; direct energy uses, such as a fuel gas; and indirect energy uses, such as production of synthetic fuels and operation of refineries.

In the next 45 years, according to the study, hydrogen consumption is projected to grow worldwide by about 7% per year on average. The greatest volume of hydrogen is expected to be consumed in the indirect energy sector, but the greatest percentage increase is expected to be in direct consumption. Slowest growth is expected to be in those countries, such as Canada, with large fossil fuel resources.

The usual variety of barriers and stimuli have been cited as influencing the future growth of hydrogen consumption, including government policies and competition from established energy sources. By the year 2025, 85% of hydrogen production will be used in the energy industry. About 16% will be consumed as direct energy and 69% for refinery operation and synfuels production. Proponents of the "hydrogen economy" can take some comfort in the increased consumption of direct energy hydrogen, but fossil fuels will still dominate the energy industry, with oil and coal being the major carbon sources.

Hydrogen production in the U.S. is projected to grow about 7.6% per year with about 65% of it going into synfuels production, probably for low- and medium-Btu gases. The hydrogen probably will be derived, says the study, from coal gasification with steam and/or electrochemical and thermochemical splitting of water. Switzerland and Sweden may become the biggest per-capita consumers of hydrogen for heating during the next 45 years. □



Scintillation detector unit to be used in particle studies

Barbara Gorby, a physicist at Harshaw Chemical Co., Cleveland, examines a 6-foot diameter detector unit designed by Washington University, built by Harshaw, and slated for use at Oak Ridge National Laboratory. The unit, with 72 thallium-activated sodium iodide scintillation crystals mounted individually on photomultiplier tubes, will become a major component in a spin spectrometer. The device will be used to study subatomic structure. Because of the spherical configuration of its chamber, the "crystal ball" makes it possible to detect gamma rays, neutrons, and charged particles traveling in all directions from an event taking place in the chamber.

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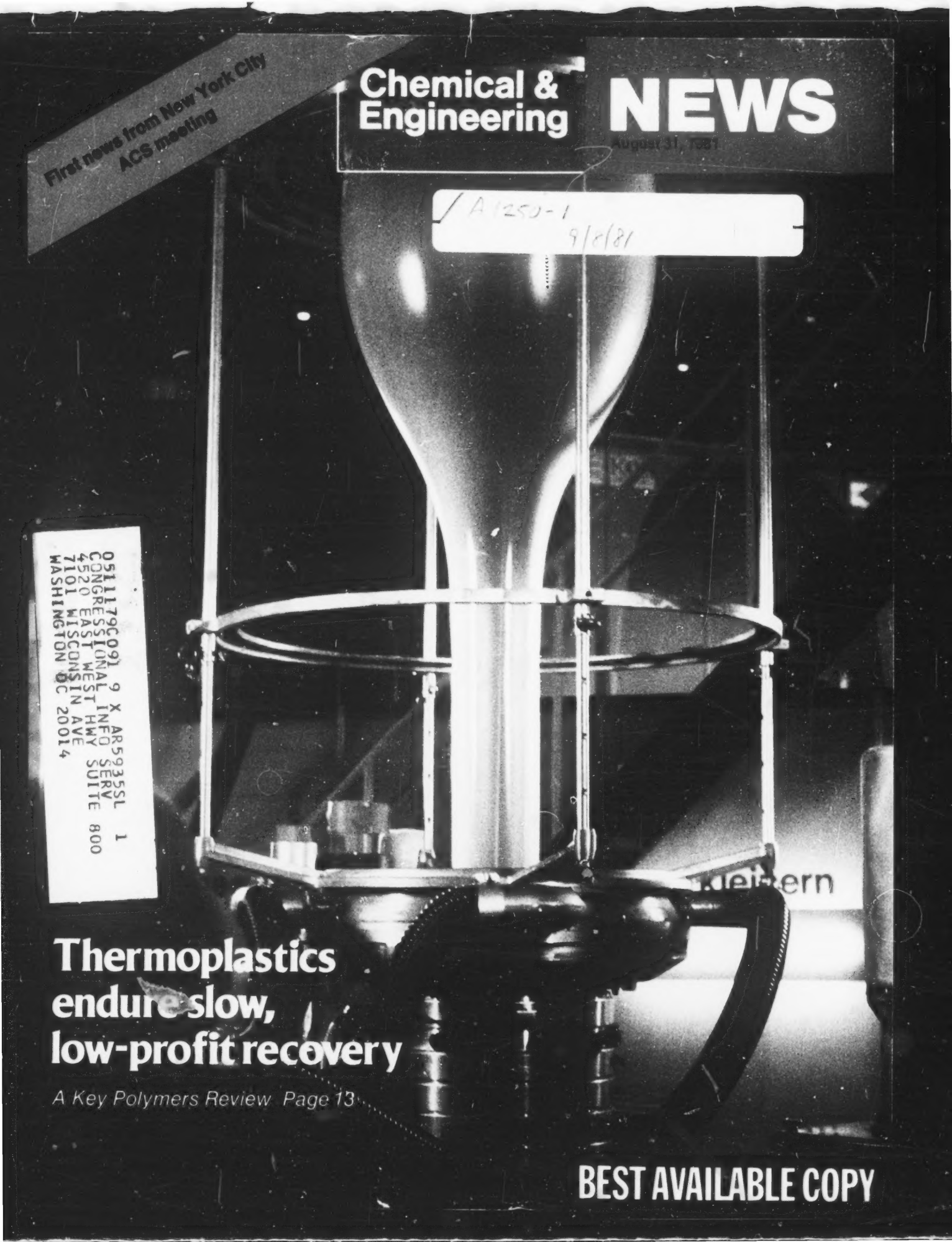

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Thermoplastics endure slow, low-profit recovery

A Key Polymers Review Page 13

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Chemical & Engineering NEWS

Cover: Extruder at American Hoechst facility blows high-density polyethylene

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News of the Week

- ***Voyager 2's high-resolution photos*** *of Saturn's rings indicate they are much more complex than was theorized, as is the planet's surface.* ***Page 6***
- ***ACS meeting in New York City*** *drew more than 11,000; highlights were plenary session on food and nutrition, panel discussion on space exploration.* ***Page 7***
- ***Robert B. Woodward Memorial Symposium*** *brought together many of the late organic chemist's colleagues and former students for a five-day program.* ***Page 7***
- ***First photos*** *from the New York City meeting focus on atmosphere, scenes typical of society gatherings.* ***Page 8***
- ***Chemical Regulations & Guideline System*** *will keep track of all federal regulations pertaining to a particular chemical via computer programs.* ***Page 9***
- ***7-Hydroxytropolone*** *is one of a new class of agents, called antibiotic potentiators, that prevent microbes from destroying aminoglycoside antibiotics.* ***Page 9***
- ***Economic impact of genetic engineering*** *on energy-producing and chemical industries will be greater than on health-care field, market research firm reports.* ***Page 10***
- ***Chick embryos can be vaccinated*** *against Marek's disease, a procedure that is eight times more effective than vaccination after hatching.* ***Page 10***

Business

- ***Recovery is slow for leading U.S. thermoplastics;*** *overcapacity, slowing demand growth rates, and buyer resistance to price increases keep profits down.* ***Page 13***

Government

- ***Food safety laws*** *due for possible Congressional reform as legislators call for review of FDA regulations.* ***Page 27***

Science

- ***Theoretical model*** *that predicts physical properties, such as lattice constant and cohesive energy, of molecules in solids developed by Berkeley physicists.* ***Page 35***
- ***Chemical data support archaeological theory*** *that maize was cultivated by Amazon basin inhabitants.* ***Page 36***
- ***Proton nuclear magnetic resonance technique*** *obtains spectra of small molecules inside intact red blood cells.* ***Page 36***

Technology

- ***Methane reforming of steam*** *will remain the chief means of hydrogen production, for chemicals or for fuel.* ***Page 39***
- ***New thermal destruction laboratory*** *burns hazardous wastes with 99.99% destruction and removal efficiency.* ***Page 40***

Recovery drags for thermoplastics

Profitability faces another hard year with low capacity use in polyethylene, polyvinyl chloride, polypropylene, and particularly polystyrene

Producers of leading U.S. thermoplastics had uncommonly good foresight about 1981 a year ago, although they probably now regret it (C&EN, Oct. 6, 1980, page 10). For 1982 and beyond, unless these companies considerably alter current plans, it's a good bet that a host of problems will forcibly rearrange this critically important product group by 1985.

A year ago, producers of these plastics—low-density polyethylene, polyvinyl chloride, high-density polyethylene, polypropylene, and polystyrene, in order of production volume—worried that reinvigorated U.S. interest rates would throttle back the whole recovery for much of 1981. Producers couldn't have been much more correct, except that now the whole year could go flat.

For 1982, industry analysts expect many of 1981's problems to be still around. Overcapacity at plants, slowing demand growth rates, and buyer resistance to price increases will keep profitability increases below what producers believe they need for future investment. On top of this, new problems may develop, notably a rising tide of imports priced lower than merely competitive.

The giant U.S. thermoplastics business, the chemical industry's best large growth area through the years, badly needs better profitability, producers say. At stake is combined production worth $11.3 billion in 1981. In the past, high profits justified large investment in new plants with lower unit production costs. Profits also produced a host of variations in polymers' physical properties, aiding market takeovers from metals, paper, wood, and other materials.

In addition, waves of research and development money have brought outstanding technology improvements. The most important recent technical breakthrough, originally Union Carbide's and Dow Chemical's revolutionary low-cost processes for "linear" low-density polyethylene, has moved well into commercialization.

The current profitability slump suggests future loss, even if temporary, of the U.S. plastics business's competitive edge. Telltale signs of a difficult profitability situation come from simple statistics on production and capacity.

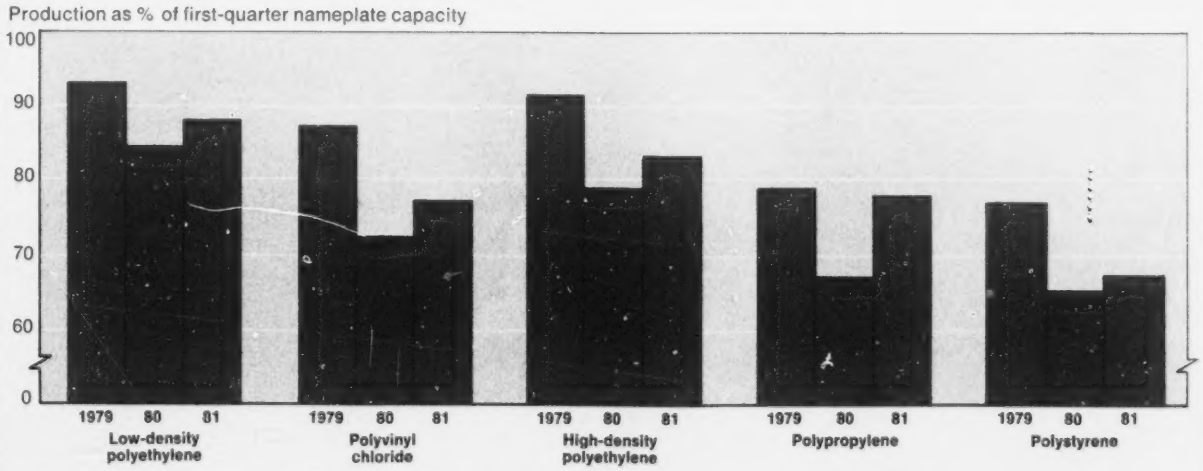
In 1981, assuming no sudden decline in the economy and higher production late in the year, total production of the five leading thermoplastics might not quite match peak production in 1979 of 26.7 billion lb. In between, production dropped 9% to 24.3 billion lb last year. The net decline in production over 1980 and 1981 from 1979 levels will total 2.5 billion lb, perhaps more.

At the same time, combined plant capacity for these five thermoplastics has increased 8.4% from 30.9 billion lb in 1979 to 33.5 billion lb in early 1981. Much more capacity, especially for linear low-density polyethylene and polyvinyl chloride, will be coming on through 1985, according to announcements from companies.

The result from 1979 through 1981 is that these thermoplastics' capacity increased 2.6 billion lb per year whereas output went down temporarily by almost the same amount. Obviously, profitability suffered, as did operating rates, going from 86% in 1979 to 79% in 1981.

A closer look at coming events for production and capacity for the individual polymers discloses major problems developing for some of

Plant use in 1981 will recoup about half the drop in 1980



Sources: Industry and C&EN estimates; Ernst & Whinney for the Society of the Plastics Industry's committee on resin statistics

them. Some polymers, for example polyvinyl chloride and polystyrene, appear to need no additional capacity from now through 1985, even assuming an optimistic growth rate in demand. In the others, demand might match or exceed current nameplate capacity in 1985. But announced expansions likely will keep capacity well above demand even for these polymers.

Polyvinyl chloride is the worst case. In 1981, production may not get back to the 1979 level of 6.1 billion lb. Nameplate capacity as 1981 began was 7.8 billion lb. Taking the high side of producers' growth range of 2 to 3% annually through 1985, production in 1985 will reach about 6.8 billion lb. This will be 1 billion lb under 1981 capacity.

But, about 3 billion lb of annual capacity either has come on stream in 1981 or is due on stream by 1985 for polyvinyl chloride. Polyvinyl chloride plants, if they all still are producing in 1985, would have to operate at 63% of capacity in contrast to 77% in 1981. The 1981 rate is itself considered low for these plants.

Polystyrene has a similar situation, though possibly not so bad. Assuming a generous 4% annual growth rate, production in 1985 will be close to 4.5 billion lb, up from an estimated 3.8 billion lb for 1981. Fortunately for polystyrene, little capacity addition is expected, perhaps as low as 300 million lb per year. This would bring 1985 capacity to 6.0 billion lb. The resulting operating rate, with no capacity shutdowns, would be 75%, up from 67% in 1981 but still well below historic levels.

Even the relatively high-flying low-density polyethylene might experience a drop in capacity use over the next few years. Assuming a 5% annual growth rate for the largest-volume thermoplastic, production in 1985 could reach 9.5 billion lb. Announced capacity expansions could bring the total in 1985 to 11.3 billion lb. The operating rate then would be off slightly at 88% in 1981.

What does the potential slump in operating rates based on these assumptions mean for thermoplastics in the longer term? Clearly, the slump won't be so bad as simple calculation suggests from current information. Producers certainly will take steps to avoid lower rates. They undoubtedly will have shut down some present capacity for polyvinyl chloride and polystyrene by 1985. Some capacity may even be scrapped by then. In other words, some shut-down units may never restart despite initial claims to the contrary.

The amount of capacity shut down will exceed by quite a bit any decline in capacity. This will result from continued technological evolution, in which new reactors and catalysts add to capacity at existing plants, especially in polypropylene and polyvinyl chloride. At this time, how much capacity will be shut down, and how much of this will be offset by improvements is anyone's guess. Some industry analysts indicate that enough units will be shut down to keep operating rates at a minimum of about 75% of nameplate capacity or higher, even in recession years.

Efforts to keep operating rates at profitable, or even marginal levels, could become difficult in the future if the import-export picture changes as some analysts expect. Rising U.S. raw material hydrocarbon prices slowly are wiping out the advantage U.S. thermoplastics have had in world markets. U.S. exports of thermoplastics will decline almost across the board this year after a long period of growth.

At the same time, there are indications that new imports are coming to compete with U.S.-produced thermoplastics. The import threat seems stronger for fabricated plastics items than for the resins, but the volume loss for U.S. resins will be parallel. Nearby countries with large supplies of light raw material hydrocarbons produced from newly developing fields of natural gas such as in Canada and Mexico are potential export boosters of plastic items to the U.S. Export incentives in these countries could be devices to, in effect, lower polymer prices for fabricators. These incentives might be enough to more than offset relatively high shipping costs to U.S. markets for many possible fabricated plastic items.

As they have in the past, U.S. producers of thermoplastics will have to cut the cost of resins to consumers to compete. Even now, price pressures are severe, resulting in widespread discounting from list prices. Big discounts apparently are keeping export sales from falling more than they have.

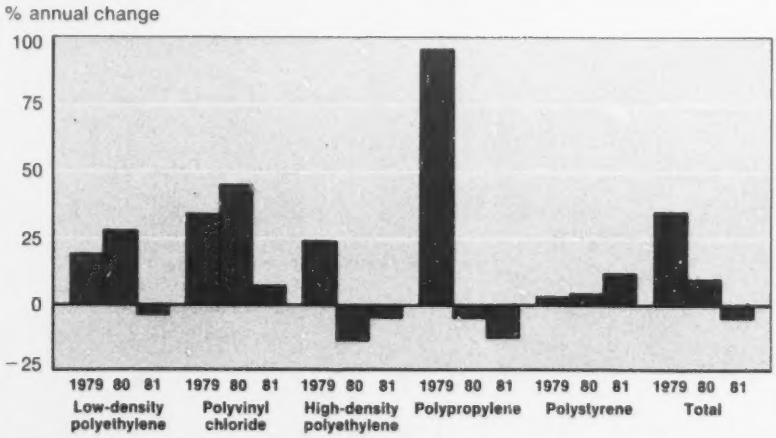
But pricing can help sales just so long before profits are gone. Then the only alternative is to improve plants or shut them down. Price pressure probably will cause many old, inefficient plants to be shut down and some expansion programs to be deferred. Therefore, the rise in capacity and decline in capacity use will be significantly less than the current exercise on paper indicates.

A tempering effect is developing, according to one industry analyst. Changes generally will be less drastic than supposed. Big capacity increases will be deferred, prices will be increased to cover costs, and production changes will be smaller than might be expected from yo-yo outside influences, such as shifts in the number of housing starts or automobile production. All these things are signs, along with the lowering of growth rate forecasts, of a maturing in the plastics industry.

For details on the immediate outlook for these thermoplastics, see the following pages.

Bruce Greek, Houston

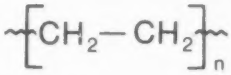
Thermoplastics exports decline in 1981 after small gain in 1980



Sources: Industry and C&EN estimates; Ernst & Whinney for the Society of the Plastics Industry's committee on resin statistics

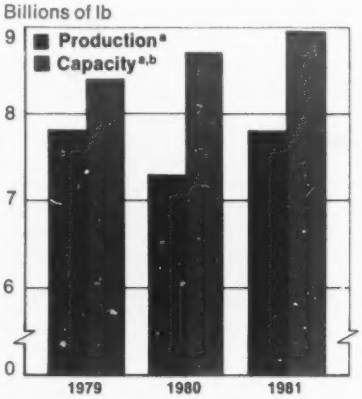
Key Polymers

Low-density polyethylene



- ***Demand recovering***
- ***Capacity edging up***
- ***Prices firm***

PRODUCTION/CAPACITY



a Includes linear low-density polyethylene.
b First quarter.

HOW MADE

Polymerization of ethylene at high and low pressures aided by initiators and catalysts

MAJOR FABRICATED FORMS (U.S.)

Film, largely for packaging, 65%; injection molding 10%; coatings 10%

FOREIGN TRADE

Exports—may fall a bit after exceeding 1.1 billion lb in 1980, imports—negligible

PRICES

Most large-volume grades listed between 46 and 48 cents a lb; discounting still going on

COMMERCIAL VALUE

$3.3 billion for total 1981 production

U.S. producers of low-density polyethylene expect 1981 production to return to 1979 volume after a 6% drop in 1980. This isn't exciting news, but it helps make low-density the most fortunate of the major thermoplastics in a decidedly unexciting year.

This means, of course, that low-density polyethylene has had no new growth in two years, like most other thermoplastics and, in fact, most other major organic chemicals.

In 1981, polyethylene production will total about 7.8 billion lb, the same as in 1979, up 6 to 7% over 7.3 billion lb in 1980. The forecast for 1981 ranges from 7.7 billion to 8.0 billion lb. The top predictions hinge on a very strong fourth quarter, buoyed by sales expectations for fabricated products following the new tax cut.

The less optimistic views hold that the impact of the tax cut on low-density polyethylene will take longer to appear. Some indication may come in the fourth quarter, especially if retail sales growth significantly exceeds inflation. However, for the sales pull in the product pipeline to get back to the polymer producers, at least another quarter may be needed. If this view is correct, a sales surge is in the offing for early 1982.

For 1981, if production of low-density polyethylene totals 7.8 billion lb, existing plant capacity will run at an average of 88% of the nameplate total for the year. This production rate, although high compared to plant use rates for many other polymers and chemicals, doesn't tell the whole story. This summer, production rates fell steeply, following relatively high rates of the late winter and early spring. Now a recovery appears to have begun. Later on, especially if production is to reach 8.0 billion lb this year, use rates will have to be near the practical operating limit of not much over 90%.

In 1981, the gain in capacity for low-density polyethylene will be small, probably a net of 200 million to 300 million lb to a nameplate total of about 9.2 billion lb. Much of the addition will be so late in the year that it will contribute little to total production. At the same time, some capacity, such as the small Union Carbide plant at Torrance, Calif., has been shut down.

In 1982, capacity will increase more as new plants come on stream and more conversion is completed on existing plants to the revolutionary linear low-density polyethylene. However, these expansions will do no more than keep up with forecast demand growth for 1982 if the economy responds as expected to the tax cut and to military spending gains.

How plant operating rates run this year could influence exports, which took a relatively high 15% of production in 1980. If demand for low-density polyethylene increases in the U.S. as expected later in the year and prices hold at current levels or increase, exports probably will fall off slightly.

In 1980, exports were 1.15 billion lb, according to data compiled by accountants Ernst & Whinney for the Society of the Plastics Industry's committee on resin statistics. So far 1981 exports have dropped slightly from year-earlier levels. The decline may accelerate as sales in the U.S. improve and recessions continue in many foreign countries, causing these countries to cut consumption and push exports.

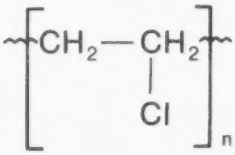
Improved U.S. sales of low-density polyethylene would not change the end-use pattern appreciably. Low-density's great strength in packaging markets will keep film at nearly two thirds of U.S. use. Of the other major end uses, injection molding may slip in percentage share because of substitution by other polymers in containers, including caps and lids.

Film's dominant position seems unlikely to be broken because all of its current uses continue to grow at least as fast as population. For many uses, the growth rate remains much higher even though industry forecasts have called for a decline. For example, demand for trash bags has yet to slacken. New uses for film still are expected, especially as more linear low-density polyethylene comes to market.

Some industry analysts expect a new jump in film use if construction returns to past levels from its current slump. Some shifting to other uses occurred as construction slowed in the past two years and fabricators sought new markets to keep their plants running. However, construction shows no signs to date of providing such a boost in 1981.

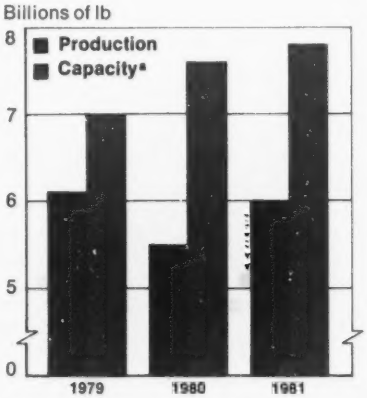
Key Polymers

Polyvinyl chloride



- ***Demand reviving***
- ***Capacity due up***
- ***Prices very low***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Polymerization of vinyl chloride by suspension, emulsion, or mass processes using initiators such as peroxides

MAJOR FABRICATED FORMS (U.S.)

Extrusions, more than half in pipe, 60%; calendered sheet and film 10%; coatings 10%; moldings 10%

FOREIGN TRADE

Exports—rising a bit to about 500 million lb in 1981, imports—negligible

PRICES

List price 32 cents a lb, higher for specialty grades; much discounting, especially on exports

COMMERCIAL VALUE

$1.9 billion for total 1981 production

Although 1980 was bad for polyvinyl chloride, production by the end of the year wasn't quite so depressed as once feared. In 1981, production will be improved, but not quite so much as once hoped.

After a good start through the spring in 1981, polyvinyl chloride production has been lower than expected this summer. Industry analysts now call for 1981 production of about 6.0 billion lb, up 9% from 1980. Some put 1981 production above 1979's record 6.1 billion lb, up to 6.2 billion lb. This would require a good fourth quarter, resulting from rising consumer spending and increased construction activity. Polyvinyl chloride is singular among major thermoplastics in its strong dependence on construction markets.

Other analysts are not so optimistic. They agree that there is pent-up demand to be filled, but they believe that consumers will wait until 1982 to pick up ordering. The resulting weak third quarter and so-so fourth quarter in 1981 won't allow full production recovery to the 1979 level.

Even if polyvinyl chloride production does match or exceed 1979's level this year, producers still will not have a good time of it. Plant capacity has increased at least 12% over the past two years, even though 1979 capacity was more than adequate to meet demand. The unfortunate result is that existing capacity of 7.8 billion lb at the beginning of 1981 will run at an average rate of 77% for the year, well down from a solidly profitable 87% in 1979.

To make the situation worse, as much as 700 million lb per year of additional capacity will be completed this year. Some of this expansion will come as new units, such as Shintech's outside Houston that will double capacity to 660 million lb per year. Many of the expansions will be small ones, however, largely debottlenecking or additional or improved reactor systems.

After 1981, an even greater amount of new capacity is due—most notably B. F. Goodrich's 1 billion lb-per-year giant at Convent, La., in 1983. Smaller new units are due elsewhere in 1982 and 1983.

These capacity increases loom at a time when demand is slack. Demand has declined a total of 600 million to 700 million lb in 1980 and 1981. This figure shows clearly the most basic problem for polyvinyl chloride—vanishing profitability. Current list prices for polyvinyl chloride sold in large volumes for major markets such as pipe and fittings have just returned to year-earlier levels. Average real-market selling prices, including export prices, also are probably up from last summer's recession.

The average polyvinyl chloride selling price, according to industry observers, has not risen nearly enough in proportion to cost increases for raw material vinyl chloride. For producers integrated backward, polyvinyl chloride price increases have not risen in proportion to cost increases in original raw material ethylene and chlorine. In addition, all of the other-than-raw material components of production cost have gone up with inflation.

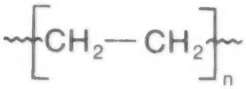
With capacity growing faster than demand and cost increases coming in all production components, the outlook seems to be for a producer shakeout. In a way, some of this has happened already as companies have sold off polyvinyl chloride plants. Most of the buyers, however, still are operating the plants, so there is no change yet in industrywide capacity.

Plants with small reactors look at first like good shutdown candidates. But in practice, producers may just replace these reactors with bigger reactors, adding to nameplate capacity.

The near-term outlook for demand isn't good. The high growth rates of the 1970's have yielded to forecasts of 3 to 4% growth per year, the better figure when construction resurges. Construction in its many facets takes most polyvinyl chloride product types, made by extruding, calendering, molding, and so on. Hence, while construction is flat, polyvinyl chloride production will tend to be low.

The background economic problem, high U.S. interest rates which hold down construction activity, also holds down sales in other, smaller-volume end uses of polyvinyl chloride such as automobiles, appliances, and home furnishings. Until the outlook improves for these durables markets, polyvinyl chloride producers will suffer smaller product volume than their invested position needs.

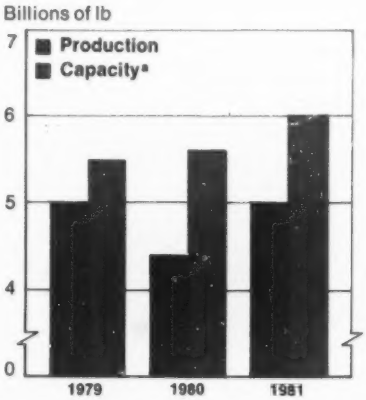
Key Polymers



High-density polyethylene

- ***Demand recovered***
- ***Capacity up again***
- ***Prices weak***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Polymerization of ethylene catalyzed by metallic salts and alkyls

MAJOR FABRICATED FORMS (U.S.)

Blow molding, mainly containers, 40%; injection molding 25%; pipe and conduit 10%; film 5%

FOREIGN TRADE

Exports—declining slowly to about 500 million lb in 1981, imports—negligible

PRICES

List price 45 to 49 cents a lb for large volume; discounting extensive

COMMERCIAL VALUE

$2.25 billion for total 1981 production

High-density polyethylene producers still expect one of the better performances among U.S. thermoplastics this year, with full production recovery from the 1980 recession. However, it will take a strong second half to see this forecast come true, since high-density polyethylene had a weak first six months.

In 1981, producers insist that output of high-density polyethylene will top 5 billion lb, matching 1979. In 1980, production fell to 4.4 billion lb, tying polystyrene for the worst percentage decline among major thermoplastics.

If 6% per year is a conservative estimate for long-term growth for high-density polyethylene, then over the past two years some 1.5 billion lb of production has been "lost." The shortfall consists of the decline in 1980 and no new growth for two years.

Still, high-density polyethylene producers are better off in their plant operating rates than are producers of other major thermoplastics except for low-density polyethylene. Even with added plant capacity in 1980, the average 1981 operating rate will be about 83% of nameplate capacity of 6.0 billion lb per year in the first quarter. This operating level is a slight improvement over 1980, when capacity of 5.6 billion lb ran at about 82%. In 1979, the rate was 91%, nearly the practical limit for this resin.

So far in 1981, production of high-density polyethylene is up less than first forecast at an annual rate. Through June, the gain was just 5.3% over the same period last year, according to data compiled by accountants Ernst & Whinney for the committee on resin statistics of the Society of the Plastics Industry. Earlier in 1981, production ran behind 1980. Recovery gained momentum in the spring, may have faltered this summer, but will renew in the fall and carry into 1982, says one analyst.

As with other thermoplastics, the outlook is for stronger demand in 1982 for high-density polyethylene. About the only large outlet expected to decline next year is exports. Although overall annual growth will fall below the 1981 initial recovery rate, production probably will increase 6 to 8% in 1982, analysts say, barring a major recession.

Hence, most of the growth will be domestic. Exports are falling this year as U.S. hydrocarbon costs rise toward world levels, and exports are expected to continue to fall as feedstock costs in the U.S. become about the same as the rest of the world over the next several years. New capacity outside the U.S. also will tend to push down U.S. exports as worldwide profitability sinks.

In the U.S. the demand recovery for high-density polyethylene seems to be occurring across the board. As a result, the use pattern will stay much the same.

Blow molding markets for products such as bottles will continue to make up 40% or more of U.S. uses. Because of its size, blow molding can be expected to increase about at the overall rate for high-density polyethylene. Slower growth in bottles of all kinds will be offset by growth in larger containers such as drums and small tanks.

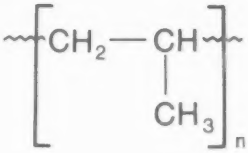
Injection molding markets rank second as a use of high-density polyethylene with about 25% of the total. This use still has some potential to take markets away from low-density polyethylene. In addition, high-density polyethylene faces relatively fast growth in crates as a replacement for wood and metal. The crate business depends heavily on the health of the returnable bottle business. This creates a trade-off with disposable milk jugs and other containers in use of high-density polyethylene and other plastics.

Use of the polymer in pipe, which along with film accounts for most of the extrusion uses of high-density polyethylene, continues to grow at an above-average rate. Construction declines have slowed demand for pipe, but an eventual resurgence in residential and commercial construction probably will speed up demand for sewer, drainage, and other pipe uses. Film's big prospect continues to be bags, mainly a capture market from paper. The weakest market for high-density polyethylene remains extrusion coatings of paper, used largely for milk cartons, which, at least in the gallon size, continue to shift to blow molded bottles.

For all of 1981, high-density polyethylene may do better than most other thermoplastics, but it still will not be like old times. Plant use is still too low, and discounting of prices is eating into profits, which remain low.

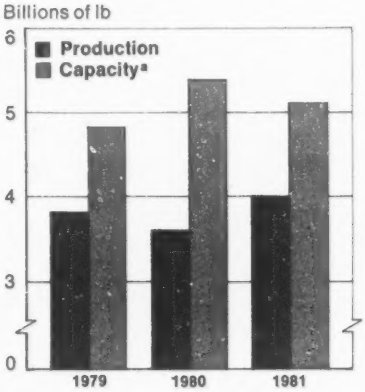
Key Polymers

Polypropylene



- ***Demand at new high***
- ***Capacity down***
- ***Prices still weak***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Polymerization of propylene catalyzed by metallic salts and alkyls

MAJOR FABRICATED FORMS (U.S.)

Injection molding, much for transportation use, 40%; fibers 35%; film 10%

FOREIGN TRADE

Exports—declining to about 600 million lb in 1981, imports—negligible

PRICES

List prices 50 to 56 cents a lb for large volume; discounting widespread

COMMERCIAL VALUE

$2 billion for total 1981 production

Of the major U.S. thermoplastics, polypropylene will provide the best record for the early 1980's. This is not to say that producers are elated over the polymer's performance. In fact, they repeatedly have been stunned by the failure of forecasts. The result is that companies are putting little money into additional plant capacity.

"Good performance" to polypropylene producers means the exceptionally small decline in production of this thermoplastic in the 1980 recession, about 200 million lb for the year to 3.6 billion lb, according to statistics compiled by Ernst & Whinney for the committee on resin statistics of the Society of the Plastics Industry. Producers also look for full recovery and even new growth in 1981 to about 4.0 billion lb.

Beyond 1981, producers foresee continued high growth (although down from historically high rates), higher production from the same units because of improved catalyst systems, and increased plant operating rates.

In 1981, the pickup in polypropylene production will be more than double the decline last year. Most industry sources expect 1981 production to exceed 4.0 billion lb, a new record, even with a slow start in the year. U.S. demand will rise even more, since producers expect exports to fall from nearly 700 million lb in 1980 to 600 million lb or a bit less in 1981.

If polypropylene output hits 4.0 billion lb in 1981, existing plants will operate at about 79% of nameplate capacity of 5.1 billion lb per year in the first quarter. This capacity is almost 300 million lb lower than it was a year earlier because of the loss of Amoco Chemicals' plant in New Castle, Del., in an October 1980 fire. The company decided not to rebuild the plant, saying that improvements in catalyst systems and other process technology would allow them to meet projected demand from their remaining plant at Chocolate Bayou, Tex.

The phase-in of new catalysts and other technology during the past two years makes estimates of polypropylene capacity less firm than for other thermoplastics. Industry analysts estimate that at least 200 million lb per year or more of capacity, perhaps 5%, will be added in 1981 without a new reactor anywhere. Some analysts also estimate that existing capacity at the beginning of 1981 was larger than 5.1 billion lb because of such debottlenecking efforts last year.

What's really needed to straighten out the capacity data question, one analyst says, is a big polypropylene demand increase somewhere. This would cause producers to run plants all out for several months and would do a lot to confirm capacity estimates. It also would do a lot for profitability, something that bulk-use grades of polypropylene have never been noted for.

As it is, running plants all out might take some time. True, polypropylene continues to gain markets through capture from other polymers, especially from polystyrene and other styrenics. This capture growth, however, is uneven, with nearly complete takeover in a few consumer products and slow inroads in others.

Over the entire polypropylene market, the big uses continue to show the major volume growth. Injection-molded items, with about 40% of the total market, probably will keep their position for a few years, but they are being threatened for top spot by fibers, which currently have about 35%.

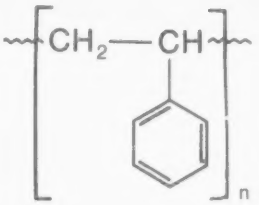
The polypropylene fiber business still holds vast potential, according to some industry observers. Although polypropylene has almost completely captured carpet backing and indoor/outdoor carpet uses from other fibers, mostly natural fibers, other "severe service" applications may be just beginning. For example, the potential for polypropylene in road bed and soil stabilization looms large.

Small amounts of polypropylene are used in various extrusion products. Drinking straws—not the largest extrusion use, but the best known—have been dominated by polypropylene for some years, but account for only about 25 million lb of resin per year. Other, larger uses are wire and cable coverings and thermoformed containers.

For this year and early next, polypropylene appears to ride on its usual attributes—great potential, fairly good sales relative to production capacity and to other polymers, and low profitability for basic grades. The most likely change will be gradually higher use of plant capacity.

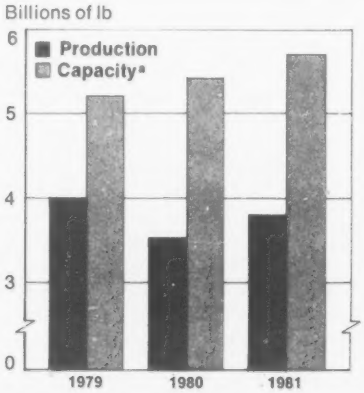
Key Polymers

Polystyrene



- ***Demand weak***
- ***Capacity up***
- ***Prices discounted***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Polymerization of styrene using a peroxide initiator

MAJOR FABRICATED FORMS (U.S.)

Injection molding 50%; extrusions 35%; beads 10%; one third of end markets in packaging

FOREIGN TRADE

Exports—falling to about 150 million lb in 1981, imports—negligible

PRICES

List prices 50 to 52 cents a lb for large volume; discounting widespread

COMMERCIAL VALUE

$1.8 billion for total 1981 production

Last, and in many gloomy ways least, among major U.S. thermoplastics is polystyrene. Producers ran into a big decline in demand in 1980 and are finding the 1981 recovery less than hoped for and less than the recovery in other thermoplastics.

In 1981, production of polystyrene probably will reach 3.8 billion lb, less than 10% above 1980 production. This means that 1981 production still will be 5% below 1979 production of 4.0 billion lb.

Some of this product's analysts have an even worse forecast. They view 1981 up just 5% from 1980's low. They believe that the production upswing in late spring didn't last and that output this summer will show little or no improvement over 1980, when output was down a third from the first quarter.

If 1981 production is 3.7 billion lb, or 100 million lb below the optimistic view, in-place plant capacity will operate at a punishing 65% of the nameplate total of 5.7 billion lb per year in the first quarter. This plant operating rate, the worst among major thermoplastics, would be well down from 77% in 1979, the last "good" year. Even at 3.8 billion lb for 1981, the consensus figure, production would give an operating rate of only 67%.

Because some polystyrene plants are shut down partly or totally, the operating rates for the other plants are a bit higher. Estimates are that between 300 million and 500 million lb per year of capacity is down. None of this apparently has been written off as yet, but restarting might be questionable in light of current and future economics. For now, this capacity is included in the industry's total, biasing the overall operating rate down.

This year, only minor additions are due for polystyrene capacity. If any of the shut-down plants actually are scrapped, overall capacity will get a net decline.

Longer term, capacity additions look tiny on balance. A few small expansions for making expandable polystyrene will be available in 1982 and 1983. One large expansion, 100 million lb per year for 1983 by Dow Chemical, officially has been shelved.

As Dow pointed out in announcing the indefinite delay in its expansion plan, profit margins have declined to levels at which capital investments must be reconsidered. Industry sources other than Dow confirm low profit margins for polystyrene. Some producers are believed to be earning nothing, just recovering raw material and operating costs.

The basic problem for polystyrene is that most uses of any size have leveled off. Demand for major end uses such as packaging, consumer products, and electrical components is about the same this year as in 1980. Exports are falling as the rise in hydrocarbon costs catches up with polystyrene, raising its average selling price in foreign markets close to world levels.

About the only bright spot in polystyrene markets is expandable beads. Polystyrene beads are finding wider use as an insulation material. Energy conservation efforts likely will help, especially if construction picks up and efforts succeed to increase use of beads in recreational vehicles.

Competition from other plastics, namely polyolefins and particularly polypropylene, has slowed growth in polystyrene and dampened prospects for future growth. Polypropylene in end products gains two ways. It costs less because of its density advantage, and it can be "filled" acceptably with cheaper inert materials, thereby lowering product cost. Such competition will hold down polystyrene growth in many end uses that were once entirely polystyrene's province, to about the level of growth in constant-dollar gross national product.

As an old, well-established thermoplastic, polystyrene's technical characteristics, close cost tie to raw material benzene prices, and its current uses are widely known. Although this information can help polystyrene in some ways, it also hinders the resin as producers of other resins work to substitute theirs for polystyrene by touting slightly improved final products costing a bit less. This substitution naturally is offset in part by continued product development in polystyrene.

In any event, the balance seems to put the immediate outlook for polystyrene at 5 to 7% production growth annually. Later in the 1980's, this rate is expected to slow substantially, stop, or go into reverse.

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n-Dodecyl mercaptan
tert-Dodecyl mercaptan
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smaller molecules, the signals from the hemoglobin protons have decayed completely by the time the spectrum is taken. The result, Rabenstein says, is an NMR spectrum with observable peaks from a number of molecules including glucose-free glycine, alanine, and glutathione.

Rabenstein uses two peaks from glutathione to study the binding of methylmercury in red blood cells and how various drugs affect that binding. Methylmercury is highly toxic. According to Rabenstein, about 10% of the body burden of methylmercury is in the blood and, of that, about 90% is in the red blood cells. Glutathione is an amino acid with a sulfhydryl group that forms a complex with methylmercury, and this causes a chemical shift in the resonance signal from a proton bound to a carbon near that group.

"The rate of exchange of methylmercury on and off glutathione's sulfhydryl group is sufficiently rapid that there is always only one signal," Rabenstein says. "The position of that resonance is a linear function of the amount of complex formed." Rabenstein says his data show that methylmercury binds at least six times more strongly to glutathione than to hemoglobin, which also contains sulfhydryl groups.

By adding various compounds to "poison" red blood cells and observing the effect on the resonance position, Rabenstein can evaluate the potential of the compounds as agents for treating methylmercury poisoning. □

Technology

Methane reforming to stay key hydrogen source

Future production of hydrogen, whether for making conventional chemicals or for high-volume use as a fuel, seems limited to those processes already in existence, unless some major technological breakthrough appears. A projection by Thomas Whaley, research manager in the Institute of Gas Technology's energy systems department in Chicago, supports the belief that even in the beginning of the next century steam reforming of methane will remain the process of choice—with a coal-based process becoming firmly lodged in second place.

After that follow numerous specialty processes that have significant, if smaller, contributions to make to hydrogen production, Whaley told the summer national meeting of the American Institute of Chemical Engineers in Detroit. Despite somewhat diminished enthusiasm for water splitting via nuclear-heat-driven processes, the search continues for an efficient thermochemical scheme. High-temperature steam electrolysis in a fusion reactor is the newest suggestion.

Catalytic steam reforming of light hydrocarbons, particularly methane, is now the least costly way of producing large volumes of hydrogen when natural gas is readily available. If higher-molecular-weight hydrocarbons are used, cost increases accordingly, but is still low.

Hydrogen purity of 93% is good enough for ammonia production, the chief consumer of hydrogen at present, Whaley points out. For other

Steam reforming is cheapest route to hydrogen

Process	Feedstock/raw material cost	Thermal efficiency	Hydrogen cost, $ per 1000 standard cu ft	Hydrogen cost, $ per million Btu
Steam reforming	Methane/$2.00 per million Btu	74%	$1.61	$ 4.76
Partial oxidation	Residual oil/$2.35 per million Btu	83	2.69	8.23
Partial oxidation	Coal/$1.17 per million Btu	59	3.66	11.20
Steam-iron[a]	Coal/$1.00 per million Btu	63	2.56	7.84
Electrolysis, conventional	Water/3 cents per kWh	76[b]	6.83	20.90
Electrolysis, solid polymer electrolyte	Water/3 cents per kWh	78[b]	4.45	13.62

a Includes 2 cents per kWh credit for by-product electric power. b Electric power to hydrogen (does not include the efficiencies involved in generating electricity). Note: Based on 100 million standard cu ft per day of hydrogen; 90% stream factor. Source: Institute of Gas Technology

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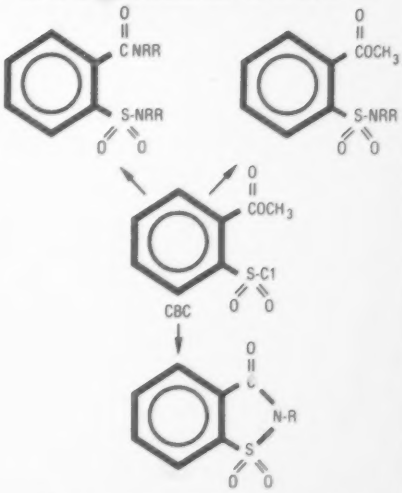

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applications, higher purity is required.

Whaley says that partial oxidation of coal and/or heavier liquids is somewhat comparable, and with conventional processing, hydrogen purities of up to 99% are possible. Even here, much of the hydrogen comes from water via the shift reaction, because coal, in particular, is hydrogen deficient.

Other processes for hydrogen production become progressively more exotic. For producing very pure hydrogen in small quantities, reaction of metals and metal hydrides with water or acids can be used. The only other high-volume process of commercial interest is the steam-iron process, but this process isn't considered viable without a way to regenerate pure iron.

Electrolysis of water is probably the oldest way to make hydrogen, but in the U.S. only about 1% of the hydrogen consumed is produced electrolytically, says Whaley. Even so, there are some rather large electrolysis plants where hydroelectric power is available. The most advanced electrolysis plant now being tested uses solid polymer electrolyte, which selectively transports hydrogen ions to an anode where molecular hydrogen is generated.

Much attention has been given to thermochemical and hybrid thermoelectrochemical cycles. Most are complex and require a high-temperature heat source for operation. Heat sources frequently mentioned are nuclear reactors, which often do not have high enough temperatures, and solar furnaces, which usually are plagued by low flux. The most studied thermochemical cycles, according to Whaley, involve sulfur compounds—which add high-temperature corrosion to the list of problems. At IGT, Whaley and his associates recently have demonstrated hydrogen production from a cadmium-based cycle using solar heat. However, so far none of the multireaction cycles have been scaled up to a pilot plant and any economic projections of processes involving thermochemical cycles are speculative at best.

One of the latest thermochemical cycles to be suggested was described at the AIChE meeting by consultant William H. Dorrance of Organization Control Services, Ann Arbor, Mich., who has reduced the number of reactions in such a cycle to two. He suggests using oxidation-reduction reactions in zeolite hosts that would appear to operate at near the Carnot efficiency limit. For thermodynamic reasons, water splitting with thermochemical cycles requires high-temperature heat, and the main thrust of the search for effective cycles has been to lower the required maximum temperature.

Of the many zeolites known, Dorrance suggests initial trials with mordenite loaded with a suitable oxidation-reduction cation pair, such as chromium-indium or bi- and trivalent europium. A crucial problem with this scheme would be the high-flux heat transfer required in the solid phase within the zeolite beds.

At present, Whaley estimates, water photolysis is being investigated in about 50 research laboratories around the world. The idea in photolytic processes is for a semiconductor to absorb light of certain wavelengths, which in turn photoelectrolyzes the water with which it is in contact. Oxygen and hydrogen are thereby produced. The concept is too new, however, to permit analysis of economic or technical feasibility.

Still another new process that has been suggested is electrolysis of steam in solid electrolyzer tubes heated with neutrons in a fusion reactor to temperatures of 1500 °C. The projected efficiency of such a process is 60%, but little work has been done on it. □

Lab optimizes burning of hazardous wastes

A new thermal destruction laboratory has gone into operation at Midwest Research Institute, Kansas City, Mo. The bench-scale facility, which can accommodate gram quantities of hazardous wastes in liquid, slurry, or solid forms, is used to determine optimum conditions for incineration and also to confirm the effectiveness of the incineration procedure.

MRI notes that incineration of hazardous wastes has become more complicated as a result of new Environmental Protection Agency regulations. These regulations establish a permit system for operators of hazardous waste incinerators. They set forth strict performance and procedural standards, including 99.99% destruction and removal efficiency for specified "principal organic hazardous components." They specify that "trial burns" be carried out before full-scale incineration of "new" wastes. And they require appropriate evidence that standards and permit conditions are being met.

According to Douglas E. Fiscus, head of MRI's applied science sec-

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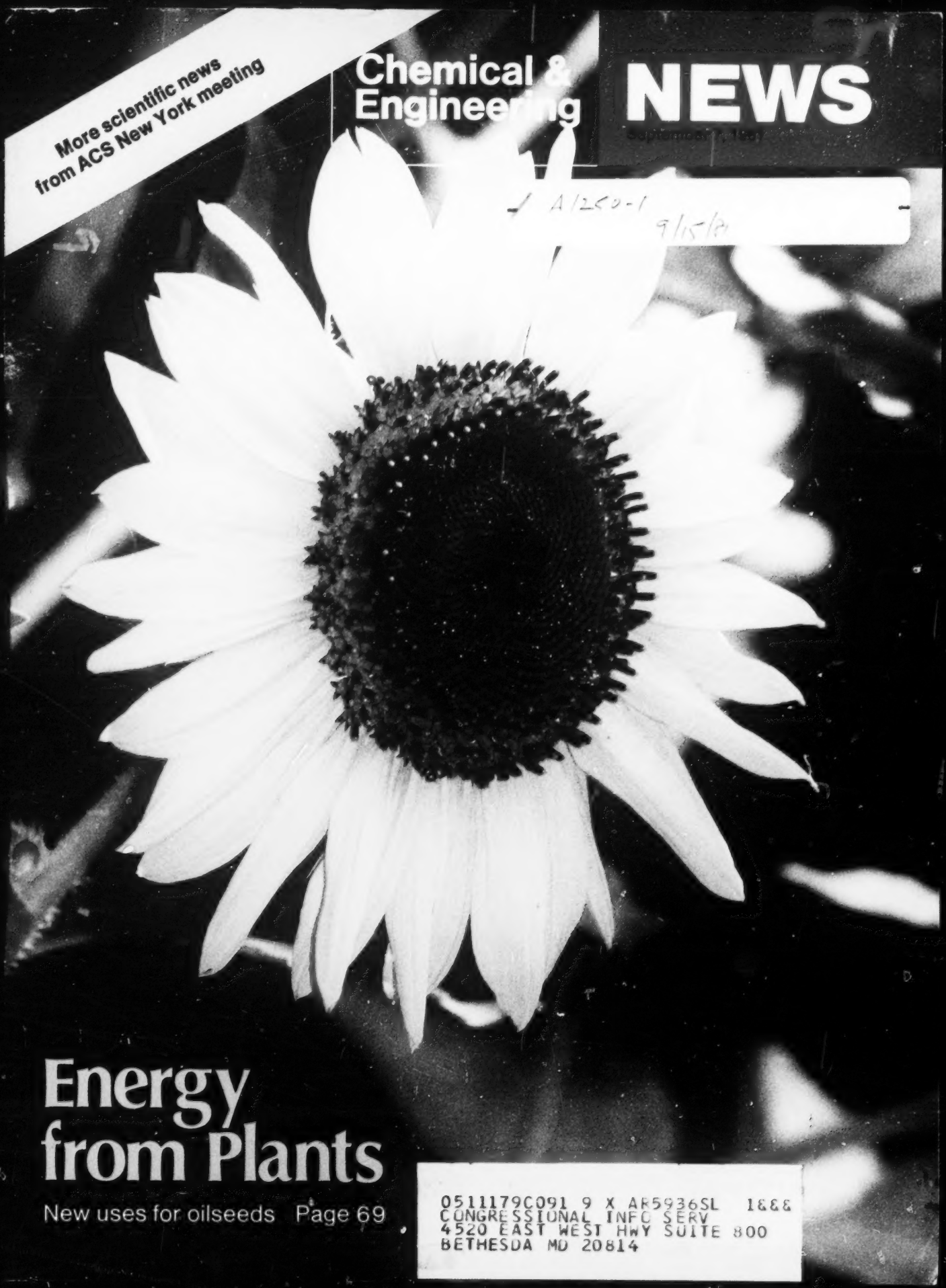

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New uses for oilseeds Page 69

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- ***Mallinckrodt*** *to support hybridoma research at Washington University.* **Page 8**
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- ***Technology advances reported*** *in New York: combining analytical techniques, absorbents for CO_2 scrubbers, vanadium from wet-process acid, in-situ combustion, uranium from seawater, decontaminating radioactive soil, chemicals from syngas.* **Page 56**

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The sunflower and the buffalo gourd *are among plants bearing oilseeds that may be useful for fuels, chemicals.* **Page 69**

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- ***Resolution of only two petitions*** *makes for short council meeting.* **Page 80**

GROWTH OF FOREIGN INVESTMENT SLOWING

The recession last year in the U.S. and abroad took its toll on both investment by U.S. chemical firms overseas and foreign investment in U.S. chemicals. Both were up, but not nearly so much as they had been in 1979, according to statistics published by the Commerce Department.

According to a Commerce Department spokesman, U.S. chemical investment abroad at the end of 1980 amounted to $19.0 billion, a 12.8% increase from year-end 1979, which had been up 18.5% from 1978.

Again, the biggest investment was in Europe at $9.7 billion. However, Europe, with a 12.1% increase in investment, was not the biggest gainer. Latin American investment at the end of the year was $3.6 billion, up 16.4% from 1979. Canada also was growing faster than Europe in terms of U.S. chemical investment. Investment of U.S. companies in Canadian chemicals at year's end totaled $3.4 billion, an increase of 14.0% over year-end 1979.

While investment abroad in chemicals was increasing 12.8% last year, foreign companies' investment in U.S. chemicals was increasing only 9.8%. Foreign investment in U.S. chemicals at the close of 1980 totaled $7.9 billion, compared with $7.2 billion at year-end 1979. This rate of increase is less than half the 18.3% increase from 1978 to 1979.

Net direct investment outflows from the U.S. for chemical investment exceeded the net direct investment inflow into the U.S. by foreign companies by more than four to one last year.

Outflows from the U.S. for direct chemical investment were $1.9 billion last year, compared with inflows into the U.S. by foreign companies of just $464 million. However, in spite of the big lead over inflows from foreign firms, outflows by U.S. investors were down 33.0% in 1980 from almost $2.9 billion in 1979. Outflows in 1980 were larger in only two areas—Latin America and Canada—than they had been in 1979. U.S. firms sent $464 million to Latin America for chemical investment last year, a 57.2% increase over outflows to that area in 1979. Outflows from the U.S. to Canada rose 3.5% to $416 million from $402 million in 1979.

By contrast, outflows to Europe last year were a little more than $1 billion, a 46.5% drop from outflows of almost $1.9 billion the year before.

Inflows from foreign sources to U.S. chemicals last year were $464 million, down 36.4% from 1979. Inasmuch as European companies are the largest foreign investors in U.S. chemicals, the sluggish European economy undoubtedly played a part in the lower rate of investment last year.

Reinvested earnings at U.S. firms' foreign chemical operations generally followed the pattern set by outflows. Reinvested earnings abroad in 1980 fell 10.9% to almost $1.9 billion from the previous year. Once again, Europe was the loser with a 25% decline to $1.0 billion from 1979. Canada and Latin America again gained. Reinvested earnings in Canada were up 5.5% over 1979 to $305 million. And in Latin America, reinvested earnings increased a whopping 64.2% to $370 million from the year before.

Reinvested earnings by foreign companies in U.S. chemical operations dropped sharply last year. Reinvested earnings were just $183 million, down 51.8% from 1979. □

Pace of U.S. chemical investment abroad cools somewhat, but so does foreign investment here

	Cumulative investment at year's end		Outflow[a]		Reinvested earnings[b]	
$ Millions	1980	1979	1980	1979	1980	1979
U.S. DIRECT INVESTMENT ABROAD						
All areas	$213,468	$186,760	$1548	$4984	$16,998	$18,964
Petroleum	46,920	38,744	−2757	3120	4,553	5,414
Chemicals	19,044	16,878	1924	2873	1,856	2,083
Europe	95,686	82,622	4962	1225	7,821	10,627
Petroleum	19,924	17,755	−101	523	2,251	2,884
Chemicals	9,695	8,646	1005	1879	1,002	1,338
Canada	44,640	40,243	370	1035	3,490	3,003
Petroleum	10,573	8,648	518	156	1,389	1,052
Chemicals	3,382	2,966	416	402	305	289
Latin America	38,275	35,056	−691	270	3,347	2,924
Petroleum	4,336	3,948	96	58	288	788
Chemicals	3,586	3,081	464	295	370	224
FOREIGN INVESTMENT IN U.S.						
Total	65,483	54,462	4664	7921	6,190	3,955
Petroleum	12,253	9,906	−324	−499	2,671	1,645
Chemicals	7,859	7,212	464	730	183	380

a Equity and intercompany accounts from country in which parent company is headquartered. b For corporate affiliates.
Note: Negative number means net inflow to U.S. for U.S. investment abroad and to foreign country in foreign investment in U.S.

Company funds university hybridoma research

Mallinckrodt Inc. and Washington University, both in St. Louis, have entered an agreement whereby the company will support research into hybridoma technology. Calling this the "largest single university-industry agreement" to support such research in the U.S., the two parties announced that the company will provide more than $3.88 million to the university during the next three years.

The research arm of the program will be guided by Joseph Davie, who is head of the department of microbiology and immunology in the university's school of medicine. Members of other departments, including pathology and internal medicine, also will be part of this joint venture.

According to the agreement, Washington University scientists will remain free to publish their research findings in the scientific literature and they also will be allowed to exchange materials, such as cell lines,

Chemical capital spending leveling off

Spending rate for first-half 1981 at 15 major U.S. firms surveyed by C&EN is up only 3.7%, indicating that level of investment is down

High interest rates and a slow economy are taking their toll on U.S. chemical capital spending. A survey by C&EN of 15 major U.S. chemical companies shows that capital spending by these firms in the first half of 1980 was $3.55 billion, a gain of only 3.7% from the $3.43 billion spent in the same period a year ago.

Even more consequential is that the capital budgets for chemical companies for the full year have been cut back in many cases. At the end of last year, it looked like capital spending would be up about 8% in 1981 from 1980 (C&EN, Dec. 8, 1980, page 19). Even this increase had seemed bad news at the time, since it followed a 21% gain in spending for 1980 over 1979, and probably would be less than inflation.

Now, however, the gain for the full year looks even more modest. The most recent survey shows that capital budgets at the 15 companies have been cut back to where, if they are fulfilled, capital spending for this year will be up only 4.7% from last year.

Since this percentage is much below the level of inflation, it looks as if the level of building for the U.S. chemical industry is declining, rather than growing, this year.

And, when 1981 is finished, the increase in spending may be even lower than the 4.7% now projected. A number of the 15 companies surveyed have spent less than 45% of their full-year budgets in the first half. It is not unusual for companies to spend less than half of their budgets in the first six months; spending at many firms picks up in the second half. However, it seems to be a danger signal if spending falls below 45% of the total budget in the first half of the year.

It is very apparent why budgets are being pulled back. Capacity use for many chemical products is not up to reinvestment levels. Thus, there is no need to build until the U.S. economy improves to the point that output from new capacity can be soaked up. And probably more important, the high cost of money is forcing companies to re-evaluate their spending plans, often deferring building until interest rates fall. Indeed, some companies have deferred entering the bond market, because the cost of entry is almost prohibitive. This means that they are financing any expansion through carry-over borrowing and by short-term financing. Carry-over borrowing is restricted because most of that money has been used in previous years, and short-term financing is expensive.

Results of the C&EN survey are borne out by a study released last week by the Conference Board in New York City. According to the board's quarterly survey, capital spending for chemicals and allied products increased 9.3% in the first quarter over the same period last year but it was up only 0.4% for the second quarter for a first-half increase of just 4.8%. In constant 1972 dollars, however, the picture was bleaker and indicates that plant building is decreasing rather than increasing. Although first-quarter spending was up 4.1% over the first quarter of 1980, constant-dollar spending in the second quarter fell 5.1%. This translates to a 1.5% decrease in constant-dollar spending through the first half for chemicals and allied products.

Capital appropriations (monies

Chemical capital spending increased only 3.7% in the first half

	First-half capital spending		%	Capital spending		%	% of budget spent in first-half	% of actual spending in first-half
	1981	1980	change	Budget 1981	Actual 1980	change	1981	1980
Air Products[a]	$ 178.4	$ 168.7	5.7%	$ 375.0	$ 364.0	3.0%	47.6%	46.3%
Allied Corp.	224.0	202.0	10.9	600.0	533.0	12.6	37.3	37.9
American Cyanamid	80.0	90.0	−11.1	190.0[b]	196.0	3.1	42.1	45.9
Celanese	170.0	105.0	61.9	400.0	253.0	58.1	42.5	41.5
Diamond Shamrock	212.3	155.0	37.0	500.0	381.0	31.2	42.5	40.7
Dow Chemical	526.3	545.7	−3.6	1150.0	1184.0	−2.9	45.8	46.1
Du Pont	710.0	613.0	15.8	1400.0	1279.0	9.5	50.7	47.9
Ethyl Corp.	85.2	87.7	−2.9	165.0	156.0	5.8	51.6	56.2
W. R. Grace	301.0	338.8	−11.2	700.0	657.4	6.5	43.0	51.5
Monsanto	296.0	397.0	−25.4	650.0[b]	781.0	−16.8	45.5	50.8
Olin	61.0	63.0	−3.2	156.0	172.0	−9.3	39.1	36.6
Pennwalt	20.1	23.6	−14.9	70.0	56.0	25.0	28.7	42.1
Rohm & Haas	64.0	36.0	77.8	150.0	93.0	61.3	42.7	38.7
Stauffer Chemical	99.6	104.2	−4.4	225.0	246.0	−8.5	44.3	42.4
Union Carbide	523.0	496.0	5.4	1100.0	1129.0	−2.6	47.5	43.9
TOTAL	**$3550.9**	**$3425.7**	**3.7%**	**$7831.0**	**$7480.4**	**4.7%**	**45.3%**	**45.8%**

a For first two quarters of fiscal year. b C&EN estimate.

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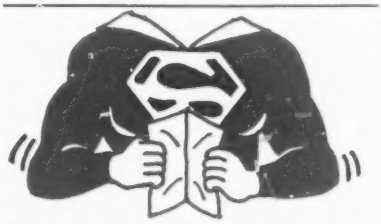

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allocated for future spending) are in even worse shape, indicating that the level of capital spending may not increase for some time.

The Conference Board finds that capital appropriations for chemicals and allied products fell 3.5% in the first quarter from the first three months of 1980. In the second quarter, current-dollar appropriations were off 13.5%, giving a first-half total off 8.6% from the first half of 1980. Once again, because of inflation, constant-dollar appropriations were off more sharply. In the first quarter, they were down 10.0% from a year earlier and in the second quarter they were off 18.3% from second-quarter 1980. Thus, for the first half, capital appropriations fell 14.2% from their first-half 1980 levels.

William Storck, New York

Powder coating group starts up programs

The Powder Coating Institute is getting off to a fairly fast start. Formed in May by the principal manufacturers serving the powder coating industry, PCI began with 14 charter members. Membership now exceeds 20, and, according to executive secretary Gordon E. Cole Jr., is expected to reach 30 by October.

PCI, located in Greenwich, Conn., also has currently completed its initial organization and is beginning to get its program under way. Four standing committees have been appointed and will direct and execute the programs toward PCI's stated aim of advancing the use of powder coating as an economical, nonpolluting, high-quality finish for industrial products.

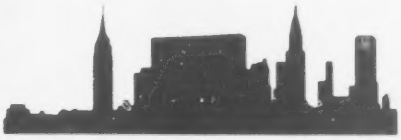
Powder coating technology is gaining more and more attention because of the advantages it offers. It is a dry painting process, involving electrostatic spraying, in which no solvents or liquid carriers are used. Since oversprayed powders simply are collected and reused, coaters are able to achieve high material use of 95% or more.

In general, powder coating can be used with most products that can be baked at the 275 to 400 °F temperatures required to flow or cure the powder. They are used not only for metal finishing but for a variety of special applications, including decoration or protection of glass, wood, and plastics.

A very active technical committee has been established for PCI, ac-

World chemical exports to continue growing

World economic cycles affect different types of chemical exports in different ways, but net trade will keep expanding at high rates



1981 ACS ANNUAL MEETING

World chemical exports have been growing at an average annual rate of 17 to 18% for the past two decades.

Yet, despite this impressive record, chemical leaders in the U.S., Western Europe, and Japan—the areas that account for three fourths of these exports—seem continuously pessimistic about the future of their chemical exports. To hear them talk, there is always something—new nontariff barriers, a new foreign plant, or a newly developing industry—waiting to knock the pins out from under their chemical export markets.

One chemical trade expert, however, thinks that these chemical leaders are overpessimistic. George B. Hegeman, manager of industrial chemicals consulting at Arthur D. Little Inc., Cambridge, Mass., believes that world chemical exports will continue to grow at or near their recent historical rates. He also believes that the U.S., Western Europe, and Japan may well strengthen their positions as leading exporters of chemicals during the next decade.

At a recent meeting of the Chemical Marketing & Economics Division in New York City, he explained why. According to Hegeman, there is chemical trade—and there is chemical trade. There are, in fact, at least five different categories into which chemical exports can be divided.

The most important is technological trade, which involves the export of proprietary products. This is the most logical of all foreign trade, because a country exports a specific chemical that is not produced in the importing country, usually because of the specialized technology involved in producing it. ADL estimates that about one third of all chemical exports involves technological trade. The percentage is slightly higher for the U.S., Western Europe, and Japan.

Balancing trade, which is required to meet the supply-demand imbalances worldwide, accounts for 20 to 30% of world chemical exports. The large scale of many new chemical plants has spurred the growth of balancing trade. Because they are so large, these plants often are not built until the market develops sufficiently to accommodate their output. Until then, the market is satisfied with imports. Balancing trade, says Hegeman, occurs most often with fast-growing chemical commodities.

Marginal cost exports account for another 20 to 30% of chemical trade and ADL expects it to remain at these levels. When plant operating rates are low, many companies push exports at less than full market price. They can do this as long as the netback is higher than the plant's variable costs.

When that price in the importing country is less than the home market price, the export can be considered dumping. Not surprisingly, marginal cost exports can disrupt market conditions in the importing country more than any other. They also are the exports that competitors fear most.

On the plus side, marginal cost exports can mean favorable prices for importing countries. However, when there is worldwide overcapacity, these exports often lead to global price cutting and little or no profits.

World chemical exports have averaged growth of 17% per year

	$ Billions				1968–78 growth	% share			
	1968	1972	1974	1978	(% per year)	1968	1972	1974	1978
United States	$ 3.29	$ 4.13	$ 8.82	$12.72	14.5%	30.2%	24.0%	23.1%	23.9%
Western Europe (net)	4.14	6.54	15.21	21.75	18.0	38.1	38.0	39.9	40.8
Japan	0.81	1.78	4.07	5.07	20.1	7.4	10.4	10.7	9.5
Subtotal	**8.24**	**12.45**	**28.10**	**39.54**	**17.0**	**75.7**	**72.4**	**73.7**	**74.2**
Canada	0.41	0.64	1.07	2.14	18.0	3.8	3.7	2.8	4.0
Australia/New Zealand	0.16	0.33	0.67	1.20[a]	22.3	1.5	1.9	1.8	2.3
Africa	0.11	0.19	0.38	0.52	16.8	1.0	1.1	1.0	1.0
Latin America	0.30	0.57	1.85	2.03	21.3	2.8	3.3	4.9	3.8
Middle East	0.03	0.18	0.65	0.34	26.9	0.3	1.1	1.7	0.6
Asia (except China)	0.21	0.45	1.13	1.78	23.9	1.9	2.6	3.0	3.3
Eastern Europe	1.22	2.06	3.51	5.16	15.5	11.2	12.0	9.2	9.7
U.S.S.R.	na	0.36	0.75	1.07	20.1[b]	—	2.1	2.0	2.0
Other Eastern Europe	na	1.70	2.76	4.09	15.7[b]	—	9.9	7.2	7.7
People's Republic of China	0.09	0.14	0.34	0.55	20.3	0.8	0.8	0.9	1.0
TOTAL	**$10.88**	**$17.20**	**$38.17**	**$53.29**	**17.2%**	**100%**	**100%**	**100%**	**100%**

a Extrapolated at 1974–77 growth rate of 15.9% per year; 1977 exports = $1,037 million. b Growth from 1972–78. na = not available. **Note:** Percentage share totals may not add because of rounding. **Source:** United Nations Monthly Bulletin of Statistics via A. D. Little Inc.

The other two types of exports—follow-on trade and tied sales—are considerably smaller, says Hegeman. On average, they account for only 12% and 11%, respectively, of world chemical exports.

As the name implies, follow-on exports are the additional overseas sales stimulated by an existing export organization that is expanding its international operation.

Tied sales can be long-term barter agreements such as those that swap crude oil entitlements for petrochemical investment. Several deals in the Middle East fall into this category. Or they may be compensation deals, such as those between Western and Eastern Europe, in which technology and equipment are exchanged for the products made in the plant.

World economic cycles affect these different types of exports in different ways, says Hegeman. Balancing trade, for instance, is extremely sensitive to industry operating rates, reaching high levels at or near the peak of the world economic cycle.

Marginal cost exports, on the other hand, tend to be countercyclical. They peak as the world economy starts increasing, but slide back into a trough when the economy does reach its peak. As the economy recedes from the peak, these exports increase again, but drop back somewhat when the economy bottoms out.

Technological, follow-on, and tied export sales tend to follow the world economic cycle, increasing during good times and falling off during recession. Since these three types of exports account for 50 to 60% of world chemical exports, it comes as no surprise to Hegeman that exports have been a steadily growing and stable business.

Unfortunately, he says, marginal cost exports receive the most notoriety because they often result in charges of dumping. This gives the erroneous impression, he adds, that marginal cost exports are the only type in the chemical trade sphere.

Because technological, follow-on, and tied sales are affected less by changes in economic cycles, Hegeman believes that, over time, the shift between balancing trade and marginal cost trade changes the driving force for world chemical exports. This change involves a switch from centers of low-cost capacity at the bottom of the economic cycle to centers of available capacity at the top.

Based on ADL's estimate of trade patterns, Hegeman notes that technological trade is more important to Western Europe than to any other region. For the U.S., balancing exports are important, whereas for Japan, follow-on exports hold the key.

Tied sales currently are of most importance to Western Europe, primarily because of its compensation deals with Eastern Europe. Marginal cost exports play a very significant role in chemical exports of developing nations.

Despite the frantic growth rate of world chemical exports (17% per year between 1968 and 1978 to $53 billion), Hegeman finds some amazing consistencies in chemical trade patterns. The share of chemical exports, for instance, held by the major exporting nations has remained almost constant at 75% of the total.

Examining the sources and destinations of chemical exports, he also finds an unexpected stability in the

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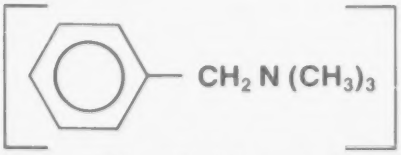
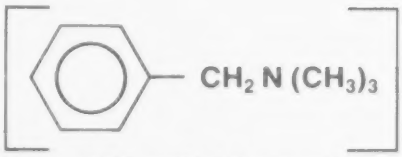


Benzyl Trimethyl Ammonium Methoxide



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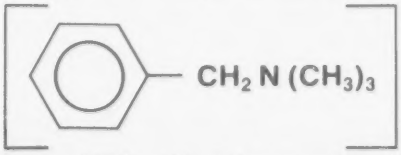

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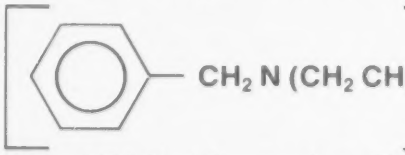

Benzyl Triethyl Ammonium Chloride

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fraction of U.S., western European, and Japanese exports destined for specific regional markets. This stability, Hegeman suggests, means that there is more of a long-term buyer-seller relationship in chemical trade than most industry leaders assume.

A corollary relationship exists in chemical import patterns as well. Although they dominate chemical exports, the U.S., Western Europe, and Japan account for only 30 to 32% of world chemical imports. Again, the percentage has remained constant over the past decade.

After analyzing these chemical trade patterns, Hegeman's outlook about the future of chemical exports goes against the grain of conventional wisdom. Conventional wisdom, he says, holds that, as new plants are built around the world, exports will decline. Hegeman believes that the reverse is true.

Building a chemical plant to produce a commodity chemical, he points out, is only the starting point in meeting growing local demand. The new producing area still will need specialty processing chemicals and advanced downstream products. As a result, technological exports from developed nations will continue to grow.

Nor is Hegeman worried that chemical exports from hydrocarbon-rich countries will pre-empt the markets of developed countries such as the U.S., Western Europe, and Japan. He thinks that the impact will be minimal.

Finally, Hegeman says that the traditional chemical producers—the U.S., Western Europe, and Japan—will remain the favorite targets for future chemical investment, especially for high-technology products. As this investment produces excess capacity in these areas, an imbalance will develop between local supply and demand. Only increased chemical trade, he says, can fill this gap.

Assuming that world economic growth continues at 3 to 4% and world chemical industry growth moves at 5 to 6%, Hegeman estimates that world chemical trade will continue to increase at 6 to 7% in real terms. Adding an inflation rate of 10 to 12% to this means that world chemical trade will continue to grow at the same rate that it has over the past 10 years. □

Plastics exports to decline steadily

1981 ACS ANNUAL MEETING

U.S. plastics exports, which have grown an astounding 26% per year over the past five years, are in for a rude awakening.

Bruce H. Pickover, manager of commercial development for Chem Systems Inc., says that plastics exports will decline steadily through 1985 as price decontrols erode the feedstock advantage that U.S. producers have enjoyed over their international competitors. Between 1985 and 1990, plastics exports will drop even more sharply as new producing units come on stream in other countries.

Pickover unfolded his sad forecast at a recent meeting of the Chemical Marketing & Economics Division in

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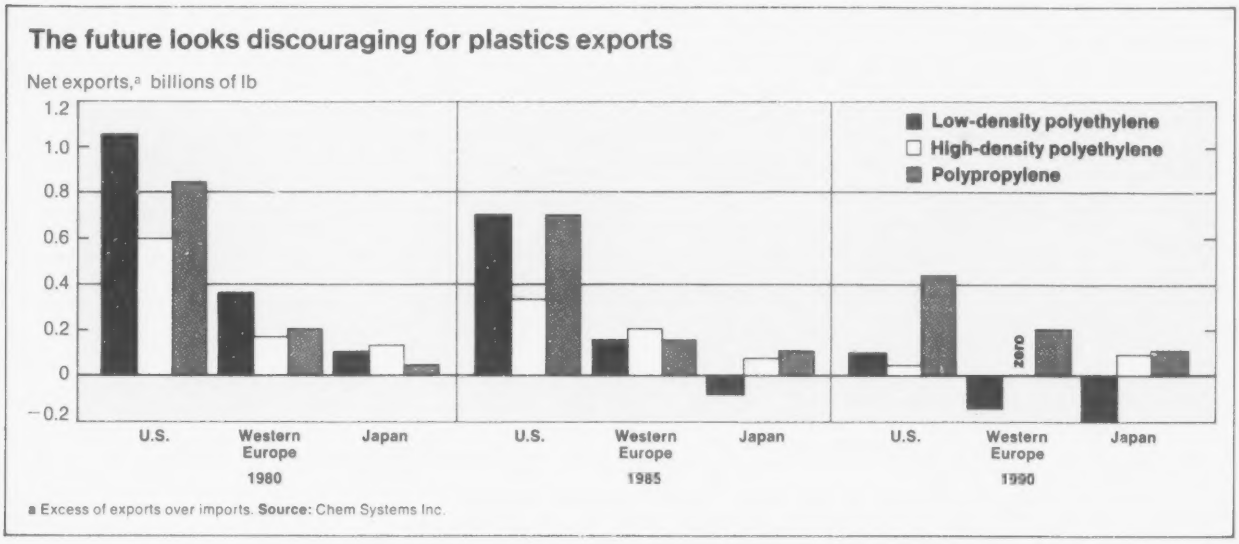

New York City. His pessimistic outlook differs considerably from the optimistic picture that Arthur D. Little's George Hegeman painted on overall chemical trade (see page 21).

Both could be right, because Pickover limited his forecast to the large-volume, commodity plastics, particularly low- and high-density polyethylene and polypropylene.

For these three major plastics, Pickover expects U.S. net exports (the excess of exports over imports) to fall from last year's 2.6 billion lb to 1.7 billion lb by 1985. By 1990, the net export figure will plummet to only 565 million lb.

As bad as that sounds, the outlook is even worse for plastics exporters in Western Europe and Japan. Western Europe, for instance, exported a net of 730 million lb of polyethylene and polypropylene last year. By 1990, it will be down to a mere 50 million lb. Japan's net exports of these big three plastics will erode from last year's 283 million lb on the positive side to a deficit of 5 million lb by 1990.

Loss of its vaunted feedstock helps explain why U.S. plastics exports will suffer. But for Europe and Japan, as well as the U.S., the big factor will be the massive capacity buildup taking place in other world areas that will inject some stiff new competition in traditional export markets.

Pickover says that most of these new projects will be based on natural gas and will not make much propylene. Thus international trade patterns for polypropylene won't change much. Polystyrene and polyvinyl chloride plants tend to be smaller and the trend will be to import the monomer.

The big impact, says Pickover, will be in polyethylene. And the greatest impact will come, not from the Middle East, but from Canada.

There is no doubt that Canada is building up its petrochemical industry with an eye toward the export market. It has a surplus of natural gas. Its national energy policy, though still not set in concrete, will keep prices low. Its relatively small population makes exporting mandatory and its well-developed infrastructure makes it easier.

Pickover counts three, four, and possibly even five petrochemical complexes being built in Alberta and at least one more in British Columbia. By 1985, new projects will add 756,000 metric tons of low-density polyethylene and 100,000 metric tons of high-density polyethylene to Canadian capacity. Longer term, oil and gas developments in northern and eastern Canada could spawn even more petrochemical complexes.

Meanwhile, Pickover says that the Middle East will have little impact on world polyethylene trade for the next few years. A polyethylene plant recently was completed in Qatar and a small unit is being built in Iraq. The big Middle East push won't come until the mid- to late 1980's, when four large projects in Saudi Arabia are scheduled to come on stream. But Pickover says that, with the country's lack of infrastructure, he doubts if they can become operational before the end of the decade.

Developments in Eastern Europe no doubt will have an impact on world polyethylene trade, particularly on Western Europe. The problem, says Pickover, is that it is difficult to predict how fast new plants will be completed in Eastern Europe.

Polyethylene projects are proliferating in other world areas as well. In southeast Asia, the ASEAN (Association of Southeast Asian Nations) countries alone will add a million metric tons of polyethylene capacity (590,000 low density and 425,000 high density) by 1990 if all planned projects bear fruit.

Construction already has started in Singapore and a plant there should come on stream in 1984 or 1985. World-scale complexes probably will be built in Malaysia and Thailand around 1986 or 1987. The timing in Indonesia is much less certain; Pickover believes that it will be completed towards the end of the decade. The Philippines, which had been considering a small complex, now is planning world-scale units.

The ASEAN region has been a big importer of plastics, especially from Japan and, more recently, from the U.S. By the end of the decade, it could be a significant net exporter.

New Zealand, South Korea, and Taiwan each have additional capacity planned for the 1980's. However, for South Korea and Taiwan, these may well be the last ones. Like Japan, these countries have no feedstock and Pickover says that they will both be net plastics importers by 1990.

In Latin America, Mexico, Brazil, Venezuela, and Argentina are increasing polyethylene capacity. There certainly will be new units, says Pickover, in other countries, such as Australia, South Africa, India, and perhaps even Nigeria.

This influx of new capacity is bound to have an impact on U.S., western European, and Japanese polyethylene exports. None of it, says Pickover, will be for the good. □

NOTE

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Acid Rain

Scientific, political dilemma

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Chemical & Engineering NEWS

Cover: Rain storm over Lake Phelps, N.C. Photo, courtesy of North Carolina Wildlife Resources Commission, by Ken Taylor

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ALASKA PETROCHEMICALS INDUSTRY FEASIBLE

A world-scale petrochemical industry in Alaska could be economically feasible in the late 1980's or early 1990's. And it could be built and operated in compliance with all state and federal health and environmental requirements. But it isn't a shoo-in.

A variety of conditions must be met for such an industry to develop, concludes a $5.5 million, year-long study by the Dow-Shell Group. The group delivered its 10-volume study last week to Alaska officials.

Since discovery of oil at Prudhoe Bay, the state has developed a concern about pursuing further economic development there. Focal point of that concern is the resources at Prudhoe Bay on the North Slope. Oil is being produced and pumped south through the Trans-Alaska Pipeline System. A plan to transport natural gas from Prudhoe Bay across Alaska and through Canada to the lower 48 states has been approved by the state and federal governments and financing plans are being evaluated.

But that leaves the natural gas liquids (NGL) that would be extracted from the natural gas. At present, natural gas and NGL are being produced with the crude oil, separated, and reinjected back into the formation.

In late 1979, state officials sought proposals from petrochemical companies for help in determining whether a petrochemical industry could be established in Alaska to utilize the NGL. Last September, the state selected the Dow-Shell Group to perform the study.

As the name implies, Dow Chemical and Shell Chemical spearheaded the study. Other companies making up the group that participated include Alaska Interior Resources Co., Alaska Interstate Co., Asahi-Dow Ltd., Du Pont, MAPCO Alaska, and Japan's Mitsubishi Chemical Industries and Mitsubishi Corp. The executive committee, representing the managements of the companies and the state of Alaska, included the Commissioner of Natural Resources of Alaska. Funding came from the members of the group.

Natural gas from Prudhoe Bay contains about 74% methane, 13% NGL (ethane, propane, butane, pentanes, and higher), and 13% carbon dioxide. The total amount of NGL is about 233,000 barrels per day, at the allowable reservoir withdrawal rate of 2.7 billion standard cubic feet per day.

Feasibility study's major conclusions

- Natural gas liquids (NGL) and petrochemical projects are economically feasible in Alaska in the late 1980's or early 1990's—under certain conditions.
- NGL project feasibility depends upon growth of real values in world crude oil, availability of ships to transport NGL to the lower 48 states, and a resolution of the Alaska Natural Gas Transportation System issue.
- Petrochemical industry feasibility in Alaska depends upon development of NGL industry with an economic supply of ethane, infrastructure development, being competitive with other world areas that can supply feedstocks, and growth of Pacific Rim markets.
- The Alaska NGL and petrochemical projects will increase the value of the state's NGL by a factor of three to seven, improve its tax base $8.6 billion to $10 billion, and help create 6800 permanent new jobs.
- Petrochemicals will be a safe industry in Alaska.
- Petrochemicals will be an environmentally sound industry in Alaska.

The study envisions a recovery of about 210,000 bbl per day of NGL. Its analysis is based on construction of an extraction plant on the North Slope to separate NGL from methane. The NGL then would be transported through a new NGL pipeline to sites or a site where it would be separated into ethane and liquefied petroleum gases (LPG), with the LPG shipped to markets in the lower 48 states. The ethane would be used as feedstock for petrochemicals. Enough ethane is available in the NGL to supply two 1.5 billion lb-per-year ethylene plants.

Petrochemical development was studied as taking place in two phases. The first phase would include plants for Dow to make ethylene (1.5 billion lb per year), Dow polyethylene (400 million lb per year), Dow/Asahi-Dow ethylbenzene (to reach full capacity of 1.87 billion lb per year in phase 2), Mitsubishi polyethylene (180 million lb per year), Shell ethylene glycol (800 million lb per year), and Dow Styrofoam (with capacity to meet the market). Phase 2 would include plants for Shell to make ethylene (1.5 billion lb per year), Dow ethylene glycol (750 million lb per year), Dow polyethylene (200 million lb per year), Shell alpha olefins (550 million lb per year), and Shell/Mitsubishi ethylene dichloride (700 million lb per year).

The study also included a group of petrochemicals—ammonia, urea, methanol, and chlorine/caustic soda—based on methane and electric power (with methane as the fuel). It also included a study of benzene production for use in making ethylbenzene.

However, before such an industry could become reality, the study emphasizes, a number of conditions must be met. A prerequisite for a petrochemical project is an NGL project, and its feasibility depends on crude oil's price rising above $38 per bbl, in 1981 dollars, for the project to become attractive to the NGL owners (Exxon, Arco, Sohio, and the state of Alaska). By the middle of 1981, average crude oil acquisition costs on the U.S. Gulf Coast had dropped to $36 per bbl.

Moreover, ships to transport the LPG must be available. They aren't currently and are estimated to have a five-year delivery schedule.

Economic feasibility of Alaska petrochemicals, the study says, depends on the cost of ethane, costs of fuel and power, and development of infrastructure. Higher construction costs in Alaska—1.7 to 2.1 times those on the U.S. Gulf Coast—require the cost of ethane at an Alaska petrochemical site to be 10 cents per lb less than on the Gulf Coast for the products to be competitive with manufacture of the same products on the Gulf Coast.

Petrochemical feasibility also depends on Pacific Rim market growth. Although there has been a slowing of demand during the past year for the products studied, the study projects that the Pacific Rim market growth for ethylene and derivatives will be enough to accommodate production

Alaskan petrochemical capital costs are high

Facilities	$ Billion
Extraction plant	$0.9–1.0
Natural gas liquids pipeline	2.0–2.4
Petrochemicals	3.5–3.8
Methanol/benzene/ Styrofoam	1.0–1.3
Sites and support facilities	1.2–1.5
TOTAL	$8.6–10.0

from Alaska in addition to other facilities supplying the market.

As for timing, if the natural gas pipeline project proceeds on schedule, it probably will be built before an NGL project. Building both at the same time would put a severe strain on Alaska's economy. □

OSHA finds flaws in workplace hazard study

The Occupational Safety & Health Administration has found serious flaws in a study conducted by the Council on Economic Priorities, which finds that despite decline in injuries and illness since 1972 the chemical industry is still a hazardous place to work.

The study (C&EN, June 29, page 6) analyzed data contained on an OSHA data tape containing records of inspection of the chemical and allied products industry conducted between 1972–79.

One general flaw mentioned in a memorandum prepared for OSHA director Thorne G. Auchter by Roland Droitsch, acting deputy administrator for policy evaluation and research, is that while the report itself provided a summary of methodological problems, it proceeded to draw conclusions as if the problems didn't exist.

"The major problem with CEP's analysis of percentages," the memorandum says, "is that the sum of the percentages must equal 100% and this really does not provide any substantive information." For example, it says the fact that a higher percentage of the inspections of the eight largest chemical firms than for the industry as a whole are accident inspections does not imply that these firms experience more accidents per 100 employees or per establishment than the rest of the industry. The percentages should be linked to number of employees or establishments if a useful conclusion is to be drawn, the memorandum points out.

The memorandum goes on to say that, although the CEP study shows that health violations cited in the chemical industry have increased dramatically since 1976, it did not mention the two most likely explanations for the increase. One is the increase in the number of industrial hygienists hired as OSHA inspectors since 1976, the other a concerted effort by OSHA beginning in 1977 to reduce the number of so-called "nit-picking" safety violations it cited.

But the most serious fault OSHA finds with the CEP report is that it doesn't even mention that the chemical industry's incidence rate of injuries and illnesses, according to the Bureau of Labor Statistics, is significantly below the rates of all manufacturing and total private sectors, indicating that the chemical industry may be far safer than most other industries. □

Robert Henze, ACS staff member, dies

Robert E. Henze, 59, director of the American Chemical Society's membership division, died of cancer Sept. 5 at his home after a brief illness.

Henze had been a member of the ACS headquarters staff for 23 years, the past 11 of which he directed the membership division. Before that he served as director of the society's educational activities and as director of the Petroleum Research Fund grants program.

Robert E. Henze

Born in Detroit, Henze received a bachelor's degree in both chemistry and botany at Miami University, Oxford, Ohio, in 1943 and a Ph.D. in biochemistry at Purdue University in 1951. He remained at Purdue to teach until 1958, when he moved to Washington, D.C., to join the ACS staff. During World War II he was engaged in rocket propellant research with Monsanto in Dayton, Ohio.

In his most recent ACS post, Henze oversaw such diverse society operations as educational activities, meetings and divisional activities, chemical expositions, membership activities (such as employment aids and local section activities), professional relations and manpower studies, and research grants and awards.

In addition to being a member of ACS, Henze was a member and twice president of the Scientific Manpower Commission (also serving in several other offices with the commission), a member of the National Research Council Board on Human Resources Data & Analysis, and a fellow of the American Association for the Advancement of Science.

An expert amateur photographer, Henze participated in numerous photography shows in the Washington area and won a number of awards for his still-life studies in black and white. He also pursued welding as an art form, producing ornaments from scrap metal and other materials. □

Work continues on sulfur paving material

Despite a worldwide tightness in sulfur supplies, research is continuing on ways to replace a substantial part of the asphalt in paving materials or the portland cement in concrete with sulfur. Among the latest developments: licensing of Japan's leading cement producer, Onoda Cement, to have exclusive rights in 16 East Asian countries to the Sudicrete sulfur concrete technology developed by the Sulphur Development Institute of Canada.

The Sudicrete process, invented by a research team at the University of Calgary, uses sulfur and a patented additive in place of portland cement and water to bind aggregate (sand, stone, or crushed rock) into concrete. As part of the 15-year agreement, Onoda Cement will conduct research and commercial development work on the process.

Although much of the initial development of this material was un-

Chemical industry productivity falling

Recession of 1980 brought greater drop than for all manufacturing; cost of energy, decreased plant capacity use are factors

A clearer picture is emerging of the decline in productivity of U.S. industry in general and the chemical industry in particular during 1980. Hammered by the recession of 1980, productivity for all manufacturing declined 2.3% during the year, according to the American Productivity Center in Houston. The chemical industry's productivity fell 2.9% last year, more than that for all manufacturing.

Estimates of productivity by APC have been revised during the past year. The base year of 1967 has been moved to 1977 and changes reflect revisions by the Bureau of Census to the 1977 industrial output estimates. APC's total factor productivity designation also has been changed to multiple-input productivity index to reflect better the data used in estimating productivity. Other minor adjustments also have been made.

Like the former total factor productivity index, the multiple-input productivity index relates output in terms of value added to the total of the economic inputs of production. These inputs include such factors as capital and labor.

The chemical industry, one of the industries covered extensively by APC in the past (C&EN, Sept. 1, 1980, page 12), follows the trend of most of the high-capital industries by being hit with a relatively high decline in multiple-input productivity during 1980. Changes during the year in the multiple-input productivity index in the manufacturing group varied widely—from a gain of 3.8% for food to a drop of 7.4% for both primary metals and transportation equipment.

APC cites some reasons for the drop in the index for all manufacturing, most of which fit the chemical industry. One reason, particularly for the index decline in the chemical industry in 1980, was decrease in plant capacity use. Another was slowdown in investment for improved technology. A third was adjustments to meet energy cost and supply conditions, such as substitution of labor for energy-intensive capital use. Declining domestic demand and increased competition from foreign producers caused large declines in the index for certain industries. Although the decline in the productivity index for the chemical industry in 1980 was only about one third that for primary metals and transportation equipment, the specter of increasing competition by foreign producers grows as domestic hydrocarbon costs keep rising for most chemical companies.

The trend of declining productivity in the chemical industry appears both to continue and accelerate. The 1980 decline in the multiple-input productivity index does follow an unusually high gain of 3.2% in 1979 over 1978. But the 1980 decline brings the index for the chemical industry back to the 1978 level. A recovery to 1979 levels may occur in 1981.

As a result, the pattern of declining growth rate may well be resumed. Until 1973, the index for the chemical industry rose steadily. Since that time, the average annual growth rate has declined. For example, between 1948 and 1965, the rate was 3.9% annually on the average. From 1965 to 1973, the rate was 4.2%. But between 1973 and 1979, the rate averaged 1.1% annually, reflecting the impact of the rapid increase in costs of hydrocarbons. APC stops short of predicting long-term decline in chemical productivity, however.

Components of APC's multiple-input productivity index show the same pattern. For chemicals, labor productivity held at 4.8% on an annual average between 1948 and 1973. Then it declined, averaging 2.5% between 1973 and 1979. The 1980 drop was 1.3% from 1979.

Capital productivity, as might be expected, has been hit hard by energy cost increases. After average annual increases of 2.2% and 3.1% in 1948–65 and 1965–1973, capital productivity for the chemical industry hit a decline, dropping an average of 1.2% per year in1973–79 and jumping to a fall-off of 5.3% in 1980.

The capital-labor ratio increased sharply in 1980 over 1979 for the chemical industry and by an even larger amount for all manufacturing. Usually an increase in this ratio indicates increased labor productivity. But with a decline in labor productivity, the increase indicates the unusual forces at work on industry, such as economic problems resulting from the second big increase in world oil prices.

Longer term, the increase in capital-labor ratio suggests an improvement in productivity will come. If it does, then a return to growth in the chemical and other industries seems likely.

Bruce Greek, Houston

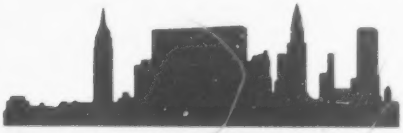
Productivity slumped in 1980 after good rise in 1979

Index, 1977 = 100	1980	1979	1978	1970	% average annual change 1979–80	% average annual change 1970–80
Multiple-input productivity						
Chemical industry	100.2	103.2	100.2	76.4	−2.9%	2.8%
All manufacturing	99.1	101.4	101.0	82.6	−2.3	1.8
Output per unit labor						
Chemical industry	103.5	104.8	100.7	70.2	−1.3	4.0
All manufacturing	101.4	101.9	100.9	79.2	−0.5	2.5
Output per unit capital						
Chemical industry	95.4	100.8	99.4	88.8	−5.3	0.7
All manufacturing	92.7	99.9	101.2	94.6	−7.2	−0.2
Capital-labor ratio						
Chemical industry	108.4	104.0	101.4	79.1	4.3	3.2
All manufacturing	109.4	102.0	99.6	83.7	7.2	2.7

Source: American Productivity Center

Mexico increasing petrochemical capacity

Nameplate capacity will almost triple by 1985, but not all products will have a surplus for export and some deficits will remain



1981 ACS ANNUAL MEETING

Many established chemical exporting countries are casting a wary eye on Mexico as a potential future competitor.

The country is blessed with an envious supply of abundant and inexpensive hydrocarbon raw materials. It has launched a petrochemical plant building program that will propel it into the big leagues of international producers.

But whether it soon becomes a significant petrochemical exporter remains to be seen. There is more—or perhaps less—than meets the eye as far as Mexico's export potential is concerned.

Petroleos Mexicanos (Pemex), the state-owned oil company that, by law, has sole control of the primary petrochemical sector, has launched a massive capacity buildup. The petrochemical complex at La Cangrejera, partially in operation already, will add 3.5 million metric tons to Mexico's primary petrochemical capacity. Construction already has started at Morelos, where the originally planned eight units have been increased to 14. An additional 36 units are planned at three other locations—Laguna del Ostion, Altamira, and Dos Bocas.

Excluding ammonia, which already is Mexico's strong petrochemical suit, Pemex will boost primary petrochemical capacity (nameplate) from last year's 2.3 million metric tons to 6.7 million metric tons in 1985 and 12.4 million metric tons in 1990.

Secondary petrochemicals, the domain of the private sector, also are slated for a capacity boost. Last year, Mexico's capacity of 20 leading secondary petrochemicals was 1.9 million metric tons. By 1985, it will be 3.6 million metric tons and, by 1990, it will increase to 4.8 million metric tons.

But capacity alone doesn't guarantee export capability, says Andres A. Trevino Bazan. Trevino, a consultant with ASPA Consultores, Monterrey, told a recent meeting of the Chemical Marketing & Economics Division in New York City that, despite a fourfold increase in petrochemical capacity during the seventies, this expansion barely kept pace with demand.

Mexican exports in the seventies, in fact, were negligible, says Trevino. Even last year, only four products were exported in any sizable volume—710,000 metric tons of ammonia and a combined total of 130,000

Mexico's exports of basic petrochemicals will grow during next decade

	Nameplate capacity			Effective capacity			Consumption			Export availability[a]		
Thousands of metric tons	1980	1985	1990	1980	1985	1990	1980	1985	1990	1980	1985	1990
Acetaldehyde	144	144	294	140	140	280	90	175	275	50	35	5
Acrylic acid	—	30	30	—	30	30	—	10	15	—	20	15
Acrylonitrile	74	174	224	70	165	210	70	120	175	—	45	35
Benzene	119	420	720	100	380	650	94	355	510	6	25	140
Butadiene	55	55	155	20	20	100	67	115	170	(47)	(95)	(70)
Cumene	—	40	80	—	40	70	31	50	80	(31)	(10)	(10)
Cyclohexane	85	205	205	70	175	175	50	130	160	20	45	15
Dodecylbenzene	73	143	143	60	115	115	97	140	190	(37)	(25)	(75)
Ethylbenzene	67	257	447	54	205	380	40	195	300	14	10	80
Ethylene	438	1438	2,338	375	1220	1,990	280	1000	1600	95	220	390
Ethylene dichloride	152	482	977	130	410	830	106	400	500	24	10	330
Ethylene oxide	28	128	328	28	115	295	60	125	170	(32)	(10)	125
High-density polyethylene	100	100	300	75	75	225	93	165	280	(18)	(90)	(55)
Isopropanol	15	15	90	15	15	70	31	20	25	(16)	(5)	45
Low-density polyethylene	99	299	540	95	285	515	195	410	650	(100)	(125)	(135)
Methanol	172	997	1,822	172	950	1,730	128	950	1110	44	—	620
o-Xylene	15	70	125	15	65	120	31	50	80	(16)	15	40
p-Xylene	40	280	520	40	265	495	134	215	240	(96)	50	255
Polypropylene	—	—	200	—	—	170	90	130	215	(90)	(130)	(45)
Propylene	324	351	828	245	300	705	124	350	670	121	(50)	35
Propylene oxide	—	—	100	—	—	85	32	55	85	(32)	(55)	—
Propylene tetramer	52	132	212	45	110	180	50	125	170	(5)	(15)	10
Styrene	33	183	333	30	165	300	108	180	275	(78)	(15)	25
Toluene	124	489	859	124	465	815	118	315	520	6	150	295
Vinyl chloride	70	270	570	63	245	515	150	240	360	87	5	155
TOTAL[b]	2280	6700	12,440	1965	5955	11,050	2265	6020	8825	465	630	2615

a Based on effective capacity. b Excludes ammonia. Source: ASPA Consultores

metric tons of dimethyl terephthalate (DMT), terephthalic acid (TPA), and methanol.

Not all chemicals enjoy surplus capacity in Mexico. Excluding ammonia, there was 700,000 metric tons of capacity available last year in Mexico to satisfy export markets. Yet only 130,000 metric tons actually was exported. The chemicals with considerable excess capacity include four basic petrochemicals (acetaldehyde, ethylbenzene, methanol, and propylene) and three secondary petrochemicals (DMT, TPA, and ethylene glycol).

By 1985, Trevino expects about 1.2 million metric tons of petrochemicals to be available for export from Mexico. But only 11 products will have a significant capacity surplus. As a result, he estimates that Mexican petrochemical exports won't top 900,000 metric tons in 1985.

Despite the heralded capacity buildup, Mexico still will have a deficit in several major petrochemicals in 1985, Trevino says. He pegs that deficit at about 600,000 metric tons, including 95,000 metric tons of butadiene, 90,000 metric tons of high-density polyethylene, 125,000 metric tons of low-density polyethylene, and 130,000 metric tons of polypropylene.

By 1990, 2.9 million metric tons of petrochemicals are expected to be available for export from Mexico. Pemex will account for more than 80% of this total, leaving less than 20% for the private, secondary petrochemical sector. Even then, some 400,000 metric tons of low- and high-density polyethylene, polypropylene, butadiene, and dodecylbenzene will have to be imported before sufficient capacity comes on stream.

Trevino believes that Mexico may even have tough sledding exporting those petrochemicals for which it will have excess capacity. Mexico, he says, will have to overcome some stiff price competition in order to sell in international markets.

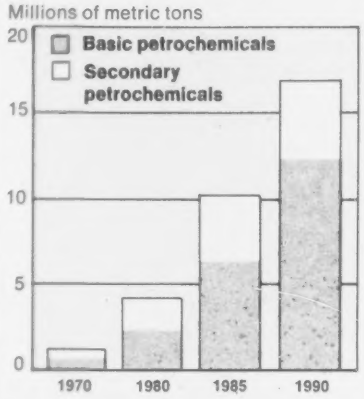
It should have no trouble with its basic petrochemicals. Pemex's low oil production costs will allow it to produce basic products and price them competitively. Secondary petrochemicals, however, are a different story. Traditionally, they have been more expensive to produce in Mexico than in the U.S.

One reason is that they have had to rely on more costly imported raw materials. Mexico has been dependent on imports to support its plastics, fibers, and elastomers industries. Of course, as Pemex builds up its basic petrochemical capacity, expensive import requirements will dwindle.

But secondary producers in Mexico still will have to contend with an economy-of-scale problem. The Mexican economy is one 20th that of the U.S. As a result, secondary petrochemical units tend to be smaller and more expensive to operate on a unit basis.

Trevino also points out that Mexico's secondary petrochemical producers are saddled with some technological constraints that not everyone knows about or appreciates. By law, they are forbidden to process refinery streams and, consequently,

Mexico's petrochemical capacity is soaring



Note: Excludes ammonia. Source: ASPA Consultores

Few secondary petrochemicals will be exported from Mexico in near future

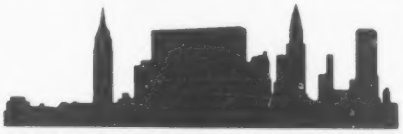
Thousands of metric tons	Nameplate capacity			Effective capacity			Consumption			Export availability[c]		
	1980	1985	1990	1980	1985	1990	1980[a]	1985[b]	1990[b]	1980	1985	1990
Acetic acid	85[d]	175[d]	200[d]	80	165	190	77	105	180	3	60	10
Acetic anhydride	33	58	115	34	58	115	34	58	105	—	—	10
Acetone	28	44	60[e]	27	40	55	26	40	55	1	—	—
Caprolactam	48	140	140	46	125	125	46	75	100	—	50	25
Dimethyl terephthalate	172	240	240	160	225	225	67	140	180	93	85	45
Ethylene glycol	180	180	180	160	160	160	61	110	145	99	50	15
2-Ethylhexanol	28	47	70	30	40	65	30	40	65	—	—	—
Formaldehyde (100%)	28	40	60	22	35	50	22	35	50	—	—	—
Phenol	25	35	60	25	35	60	22	35	50	3	—	10
Phthalic anhydride	32	52	80	30	50	75	30	50	75	—	—	—
Terephthalic acid	135	190	190	130	180	180	57	95	125	73	85	55
Urea	435	1260	1760	300	880	1450	430	850	1450	(130)	30	—
Vinyl acetate	26	40	80	26	40	75	26	40	75	—	—	—
Dioctylphthalate	44	70	85	40	70	80	40	70	80	—	—	—
Polyvinyl chloride	140	310	410	134	295	390	134	280	325	—	15	65
Polystyrene	110	135	205	100	125	200	100	125	200	—	—	—
Styrene-butadiene rubber	90	115	160	80	105	145	70	115	160	10	(10)	(15)
Acrylic fibers	80	140	190	70	125	170	60	110	160	10	15	10
Polyester fibers	145	245	355	130	220	320	130	220	320	—	—	—
Nylon	50	90	120	47	85	115	47	75	100	—	10	15
TOTAL	1915	3605	4760	1670	3060	4245	1510	2670	4000	290	595	260

a Estimate. b Projection. c At effective capacity. d Includes vinyl acetate process by-product. e Includes phenol by-product. Source: ASPA Consultores

frequently must select more cumbersome and expensive routes to produce some chemicals.

To counter these disadvantages, the Mexican government offers a 10% tax rebate (or "CEDIS" as it's called) for qualified manufactured exports. In addition, secondary petrochemical producers receive a "petrochemical CEDIS." New producers can receive discounts on basic raw materials, electricity, and fuel up to 30%, all of which makes them more cost competitive. □

U.S. engineering firms losing global business



1981 ACS ANNUAL MEETING

U.S. engineering and construction companies have lost a big chunk of their worldwide business in building hydrocarbon processing facilities.

And, unless some changes are made—and quickly—they will have trouble securing a fair share of that business in the eighties. That's the bleak warning that Lummus Co.'s H. T. Gouldon gave at a recent meeting of the Chemical Marketing & Economics Division in New York City.

U.S. engineering and construction companies face many handicaps and disincentives in their battle for world markets against their European and Japanese counterparts, says Gouldon. From their own government, they have to contend with inadequate, unreliable, and unimaginative financing. Meanwhile, many of their foreign competitors enjoy low-cost, government-subsidized financing.

Export licensing controls that depend more upon the political climate than economic realities are another handicap. So are a host of other legislative disincentives, such as the Foreign Corrupt Practices Act.

As a result of these handicaps, U.S. engineering and construction companies have watched their share of the world market dwindle. In 1976, says Gouldon, the U.S. led the world in total dollar value of contracts received—$8.6 billion, or 16% of the world total. By 1979, the value of contracts held by U.S. companies had declined to $1.9 billion, or less than 5% of the total.

In the Middle East alone, U.S. engineering and construction contracts fell from $4.6 billion to $650 million between 1976 and 1979. That drop pushed the share down from 14% to only 2.8%. If that trend continues, U.S. companies will be hard-pressed to cash in on a booming market in the eighties. Between 1981 and 1990, Lummus estimates that $585 billion (in constant 1980 dollars) will be spent on hydrocarbon processing facilities. About 60% will be available to engineering contractors. The remaining 40% will stay in-house.

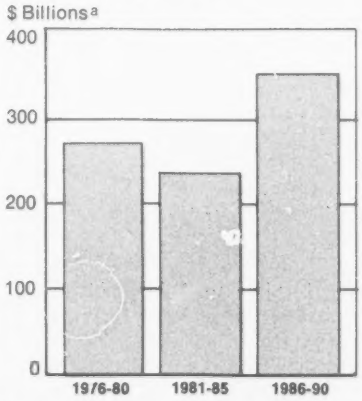
To capture a share of that business, U.S. companies will have to compete against new, as well as traditional, rivals. Japan and Korea already are major factors in the worldwide engineering and construction business. They figure to become tougher in the future, says Gouldon. And he expects such countries as India and China to play an increasingly important role.

Although Gouldon says that U.S. contractors cannot and should not compete with the inordinate risk taking and "fighting ship" pricing policies of these countries, there are other advantages that U.S. companies should be able to meet head on. These are the government-sponsored financing facilities that these countries enjoy, their ability to reach quick decisions, and their lack of self-imposed restrictions.

Gouldon calls adequate financing an indispensable ingredient to success in most world areas. Inflation, increased size, and out-of-the-way siting have added to plant costs.

A typical project cost $50 million to $60 million a few years ago, says Gouldon. Today, that same project costs about $300 million and a $1 billion project is no longer exceptional. These "megabuck" projects take about two years to develop. Bidding time alone runs six or eight months.

New plant spending will perk up by 1990



a World capital commitments for hydrocarbon processing facilities in constant 1980 dollars.
Source: Lummus Co.

That's why U.S. engineering and construction companies have to have financing in the amounts required when required. But Gouldon says that, in the U.S., financing is unreliable because of inadequate funding and an inconsistent long-range government policy.

He credits the U.S. Export-Import Bank (Eximbank) with doing a remarkable job of financing exports in past years. But today, says Gouldon, Eximbank funding hasn't kept pace with inflation or increased project scale. Partly, this is because the government doesn't recognize the extent of today's project financing requirements. And partly, he adds, the problem is caused by the year-to-year budgetary funding of Eximbank.

Flexibility also is lacking in U.S. financing. Overseas companies, says Gouldon, might benefit from a mix of developing country assistance funds, export credits, and even financing for local expenditures. The result is a lower overall interest rate and an overall longer term.

Many foreign countries provide subsidized, low-interest financing, often contrary to international agreement. Although Gouldon doesn't suggest that the U.S. follow suit, he does think that it should take countermeasures against subsidized financing.

A critical part of the U.S. financing problem is that the top officers of Eximbank are appointed by the president. That, says Gouldon, means changes, usually every four years. He suggests that Eximbank's top officers should receive tenured appointments, as they do at the World Bank and Federal Reserve Bank.

Gouldon says that the need for the U.S. to maintain export licensing controls is undeniable. But lack of a consistent, reliable policy is a big problem for U.S. companies. Too often, a U.S. company spends a lot of time and money to establish an overseas business relationship, only to find that a change in the political climate has triggered a change in export licensing procedures.

To overcome such handicaps, Gouldon wants to see the U.S. develop a consistent international commercial policy. "It's time we had one," he says. □

Acid pollutants: hitchhikers ride the wind

Scientific uncertainties, political and economic quandaries cloud attempts to understand and control potential devastation caused by wind-borne emissions

Lois R. Ember
C&EN, Washington

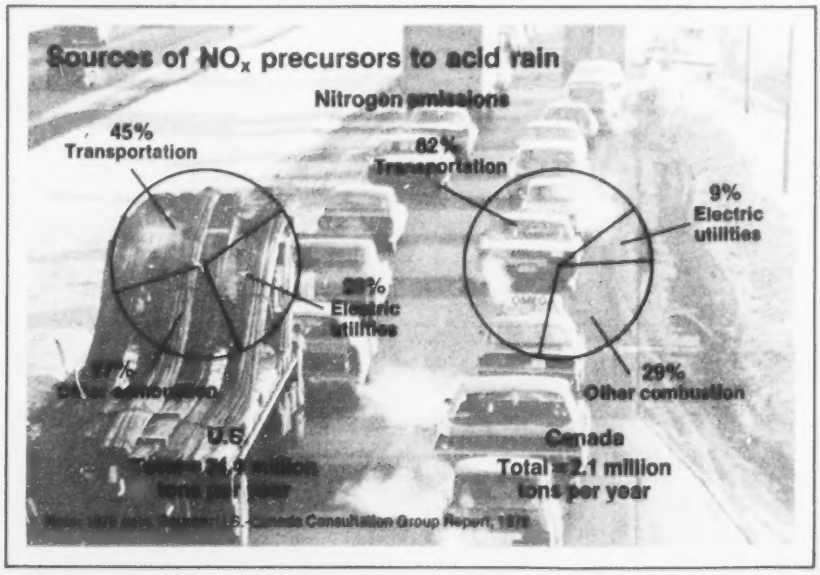
In Canada it has been called an "ecological holocaust." In the U.S., Office of Management & Budget director David Stockman has denied its existence. Canadians are concerned that their major industries—fisheries and lumber—may be devastated by the acid onslaught. Midwestern coal miners fear the loss of their jobs. Acid rain may not be the most important environmental issue of the decade—global carbon dioxide buildup may be a more intractable problem—but it undoubtedly qualifies as the most emotional.

Canada is bearing down on the U.S. to regulate those pollutants that cross the border with the winds and rain down on the provinces as acids without linking the problem to other issues such as energy exports. The U.S. is trying to appease the Canadians short of legislating, buying time to understand the problem before it regulates.

At stake in this high-rolling political game are the economies and social well-being of both nations. The chips are lakes and aquatic life, forests, agricultural lands, monuments, buildings, cars, and perhaps even health. In the balance is the risk of ecological damage or economic disaster—or both. And while the dice are rolling, acid rain's bitter potion of scientific conundrums and political quandaries has the corrosive potential to rent the federation—pitting state against state or region against region—and to sever the long-standing alliance between the U.S. and Canada.

In short, acid rain may well be the catchy shorthand term for the environmental paradigm of our times. It is the result of a technological fix: Tall stacks, built to eject pollutants high into the atmosphere where they could hitch rides on prevailing winds, solved local air pollution problems but failed to repeal one of Newton's laws—what goes up must come down. Local air pollution problems became regional ones. So for all our technological cleverness, we may be becoming servants rather than masters of technology, warns San Diego University biologist Mary E. Clark.

Servant or master aside, acid rain also spotlights two other modern dilemmas. One—the basic conflict between the need to respond quickly to ameliorate a problem and the need to gather enough scientific information to respond responsibly. The other—that pollution is often the by-product of some action beneficial to society and the cost of pollution must compete with the cost of controlling it.



Like its brethren issues, global carbon dioxide buildup and stratospheric ozone loss, acid rain recognizes no state or national boundaries. As such, it becomes a unifying principle that defines the global village. Canada's Governor General Edward Schreyer reminded President Ronald Reagan of this on Reagan's visit to Canada in March. "If this is the era of the global village," Schreyer said, "then welcome to the house next door."

He might also have pointed out that the shared airshed between Canada and the U.S. is a village commons that can't be "overgrazed" lest, in biologist Garret Hardin's words, "the tragedy of the commons" besets both nations.

In this instance, the commons is being overburdened with the by-products of industrial activity, electric power generation, and transportation. Sulfur dioxide and nitrogen oxides spewed from these sources are further oxidized in the atmosphere. If they fall back to Earth near the source as dry gases or particles, a small percentage will later combine with precipitation to form acids. But, if they are sent aloft through tall stacks they can travel the prevailing westerly winds for hundreds of miles over a period of several days. During this travel they can be transformed chemically into sulfuric and nitric acids that are scavenged by precipitation and fall on leaves, soils, lakes, and man-made objects as rain, snow, sleet, and fog. Both dry and wet deposition are colloquially lumped together as "acid rain."

How the acid precursors are chemically "processed" is poorly understood. But the classical photochemical gas-phase reaction between sulfur dioxide or nitrogen oxides and

the hydroxyl radical is now believed to play a less dominant role. More important, some scientists believe, is the processing factory residing in the clouds; tantalizing hints from field experiments point to hydrogen peroxide or another oxidant as the processor that manages the rate of conversion of precursor to acid.

Whatever the transformation mechanisms may be, acid rain with a pH of 3 to 4 is falling over the eastern U.S. and southeastern Canada. Florida and the Carolinas report acid rain. The sensitive Boundary Waters Wilderness Area of Minnesota is receiving an acid onslaught from both the U.S. and Ontario. Isolated spots in Oregon, Washington, and British Columbia are measuring precipitation at pH levels below 5.6, the conventional cutoff between acid and alkaline precipitation (pH 5.6 is the value of atmospheric carbon dioxide dissolved in water). And in 1980, scientists from the University of Colorado reported "unexpectedly low pH values" of precipitation collected in the Como Creek watershed, high in the Rocky Mountains, 4 miles east of the Continental Divide. More recently, acid fog with a pH of 3 has been recorded in Los Angeles.

In contrast to the composition of acid rain falling in the eastern U.S. and Canada, the precipitation falling at Como Creek appears to be dominated by nitric acid. In the East, sulfuric acid, by a factor of two, appears to be the main component of acid rain.

Although there are natural sources of acid—lightning, volcanic eruptions, anaerobic decomposition of organic matter, airborne sea salt sprays—most scientists would agree that the acid rain falling on Scandinavia, the U.S., Canada, and possibly Japan and China traces its origin to the combustion of fossil fuels.

In North America, a whopping 80% of sulfur pollution is generated east of the Mississippi River, mainly in pockets concentrated around Sudbury, Ont., smelting facilities, and in the Ohio River Valley—Illinois, Indiana, Ohio, Pennsylvania, West Virginia, and Kentucky—where high-sulfur coal is burned largely unchecked in large power plants. Two thirds of the sulfur dioxide generated in the U.S. comes from thermal power generation, but industrial sources contribute a hefty share. In Canada, smelters are responsible for 40% of the sulfur dioxide produced. Transportation is the main source of man-made nitrogen oxides in both countries.

The airshed shared by the U.S. and Canada is a two-way corridor carrying pollutants in both directions, but not equally. In a joint research effort, U.S. and Canadian scientists have determined that the net flux of sulfur compounds, the precursors to the dominant component of "eastern" acid rain, is from south to north. In fact, Canada claims that 50% of its acid rain originates in the Ohio River Valley, and that it sends back only 10 to 15% of the sulfur compounds contributing to acidity in the U.S.

No matter the extent of contribution, the prevailing winds carry the acid pollutants to areas in both countries least able to buffer them. The soils in the Adirondacks, Nova Scotia, Quebec, and Ontario are thin and low in alkalinity. The acidity that would be removed in well-buffered soils is, in these thin soils, allowed to percolate down to groundwater or to run off directly into lakes and streams essentially unneutralized. As a result, the chemistry and biology of the affected soils, vegetation, and waters are altered considerably.

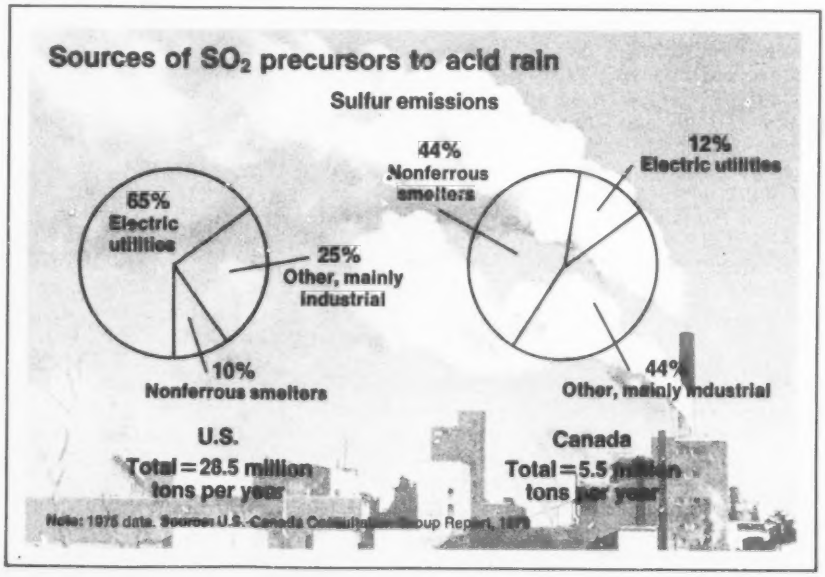
The Scandinavians were the first to make the connection between fossil fuel combustion and atmospheric acidity. In the mid-1950's they set up a monitoring network across northern Europe. After 15 years of measuring for sulfates and nitrates they noticed a "dramatic change" in the composition of precipitation, explains Henning Rodhe of the University of Stockholm.

Winds sweeping over the industrialized areas of England and the Ruhr Valley of West Germany picked up and processed the acid precursors, only to dump them unceremoniously on vulnerable mountain lakes and streams in southern Norway and Sweden. "Sulfate levels were going up and acidity was increasing," Rodhe says. At the same time, fish populations in those affected waters were declining. In 1959 Norwegian fisheries inspector A. Dannevig linked the two phenomena. Ten years later, Swedish scientist Svante Oden charted the spread of acidity in northern Europe.

Taking their cue from the Scandinavians, American scientists Gene Likens, F. H. Borman, and C. V. Cogbill, over a period of several years in the early 1970's, legitimized acid rain as an issue worthy of study in the U.S. Using the meager data available for the periods 1954–55 and 1972–73, they mapped what they believed to be increasing and spreading acidity. From a central core encompassing the Northeast and parts of the Ohio River Valley they mapped the spread of acidity south toward Florida, west toward Illinois, and north into Canada.

However, the marked increase in acidity (from pH 5.6 to about 4.5) from 1955 to 1973 noted by Likens and associates may be more apparent than real, claim scientists from the coal and utility industries. They cite the work of Richard Semonin of the Illinois State Water Survey.

Semonin contends that the higher pH values recorded or calculated for the mid-1950's were due to alkaline agents calcium and magnesium kicked up by the dust storms of the drought-ravaged Northeast and Midwest. When Semonin substituted more "normal" alkaline levels for the 1955–56 data, he found hot spots of



pH levels ranging from 4.3 to 5.0 all across the U.S.

More recent precipitation data coming from two national networks (the National Atmospheric Deposition Program—NADP—and the Multistate Atmospheric Power Production Pollution Study—MAP3S) and the Canadian Network for Sampling Precipitation confirm Likens and his colleagues' finding of expanding areas of high acidity (pH 4.5 or lower), if not a trend for increasing acidity. Says Likens: "People are quibbling about this and that, but the fact is acid rain is falling and at very high concentrations in the eastern U.S. and Canada. That area has increased in size rather dramatically since 1955; and we have confirmation that about 1930, the rain was not acid in the U.S." Nor was precipitation acid before the industrial revolution. Arctic snows that fell around 1800 and were preserved as ice in glaciers are generally above pH 5.6. The pH of ice cores from Greenland range even higher, from pH 6 to 7.6.

Yet there are disturbing, unresolved problems that make it difficult even to know what the true pH of "pure" rain ought to be, although some scientists believe it to be far below 5.6. Why, for example, are National Oceanographic & Atmospheric Administration scientists finding acidic precipitation (pH 4.7) in remote oceanic areas of the world? Are the sources natural emissions of reduced sulfur compounds from the ocean? Or are the sulfates imported over long distances from industrialized centers of the world?

Why is there no strong trend in acidity evident even at the longest (17 years) continuously operating monitoring station in the U.S. at Hubbard Brook Experimental Forest in the White Mountains of Vermont? "This is bothersome," says atmospheric chemist Ralph Cicerone of the National Center for Atmospheric Research, "because emissions of gaseous pollutants in the area to the west and south of Hubbard Brook, pollutants that feed the precipitation at Hubbard Brook, have increased, though not drastically." Yet this increase is not reflected in increased acidity as monitored at that site.

Other questions also go unanswered. Why is there a shift in dominance of acidity from sulfuric acid to nitric acid? Is it the result of changing source-emission patterns or source controls? Or is it, asks Cicerone, the result of some complicated, poorly understood, nonlinear chemical reactions? More sulfuric acid forms in summer than in winter, yet sulfur dioxide emissions remain fairly constant throughout the year. Can this fluctuation be explained by the same nonlinear reactions? Probably, but nobody knows for certain.

If there are so many unanswered scientific questions, why is there a clamor for regulating the sources of acid precursors? Quite simply, damage reports on fragile ecosystems in the Adirondacks, in southern Ontario, in Nova Scotia, and along the Minnesota-Ontario border in the Boundary Waters Wilderness Area are mounting.

Every environmental hazard has its own biological monitor. Canaries carried into mines warned miners of the presence of deadly but odorless methane gas. Dead fish may be the biological monitors for acid rain.

In 1975, Cornell University scientists surveyed 214 high-altitude Adirondack lakes. Eighty-two of these were devoid of fish; 51% had a pH of 5 or less, a value critical to the survival of fish. In contrast, in the 1930's only 4% of the lakes supposedly had a pH below 5.

According to aquatic biologist Martin Pfeiffer, there are some 2877 lakes and ponds in Adirondack Park. Since 1975, he and his coworkers at the N.Y. Department of Environmental Conservation (DEC) have surveyed 849 lakes. They found that 25% were "critically acidified below pH 5." More precisely, 264 lakes and ponds, totaling some 11,000 acres, have a pH of less than 5 and are incapable of supporting any viable sport fish. An additional 256 lakes and ponds, totaling some 63,000 acres, "are in danger of reaching a critical level of acidity" for fish, says Robert F. Cross, press aide to DEC commissioner Robert F. Flacke.

New York has been adding calcium compounds to lakes—a short-lived corrective measure—since 1959. Because of cost, the program has shrunk over the years. Today, Pfeiffer says, only six or seven lakes—about 200 acres—are limed to protect important native strains of brook trout or to provide fishing at campsites frequented by tourists. Pfeiffer is now determining the effectiveness of the liming treatment. This July his group collected water samples from previously limed waters. In general, their preliminary findings show liming to be effective, that is, able to maintain the pH at a level viable for fish for two to three years.

Like New York's DEC, Canada's Department of the Environment and the Ontario Ministry of Environment also have kept a fish death watch. They report that more than 140 lakes are so acidified that no fish swim in them. A staggering 48,500 additional lakes are threatened and could be fishless in a decade if no action is taken to reduce emissions soon. To the east, nine rivers in Nova Scotia, once teeming with salmon, now have a pH below 4.7 and are barren. Eleven more rivers are threatened.

Lakes in Minnesota also are being ravaged by acid. The Minnesota Pollution Control Agency has just completed a two-year survey of 175 lakes. It reports that the lakes show a decrease in alkalinity that correlates with the history of acid precipitation in the state. The agency expects the most sensitive lakes to go acid within this decade. Alan Watson, chairman of the environmental group, Friends of the Boundary Waters Wilderness, says 87 of those 175 lakes surveyed are in the 1 million acre Boundary Waters Canoe Area, and "83% of these lakes are classified as susceptible. Their buffering capacity is close to being overwhelmed." This confirms the 1979 findings of Environmental Protection Agency scientist Gary E. Glass.

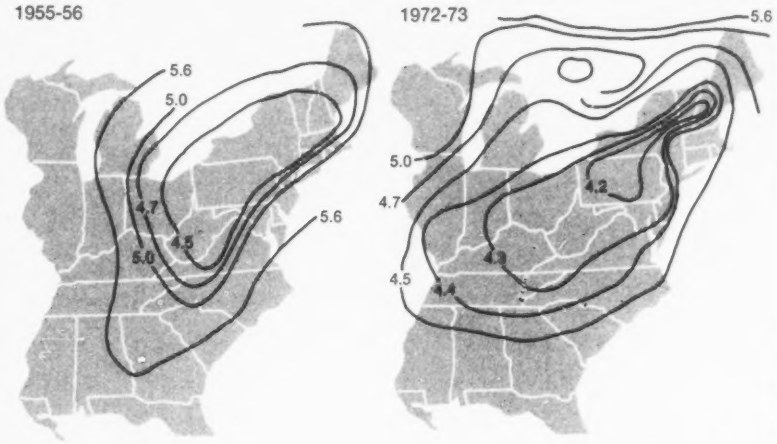
Though widely dispersed, the sensitive lake regions in the U.S. and Canada share a common geological history. In the last Ice Age, 250 million years ago, the continent was glaciated. As the glaciers moved southward they scraped away the surface, hollowing out basins and pushing around soils. In the end, a random, thin mixture of soils with different buffering capacities was laid down. Today, adjacent watersheds may possess different abilities to buffer acidity, although Ontario Ministry of Environment limnologist Tom Brydges says "only a little bit of alkalinity in the watershed is needed to neutralize the small amount of acid falling in precipitation."

It is the soils in the watershed that neutralize more than 90% of the acid in precipitation. Only a small amount of acid ever gets to the surface waters directly, and that usually occurs during the spring when the accumulated snow melts, flushes rapidly into lakes and streams, and temporarily overcomes the buffering capacity of these waters.

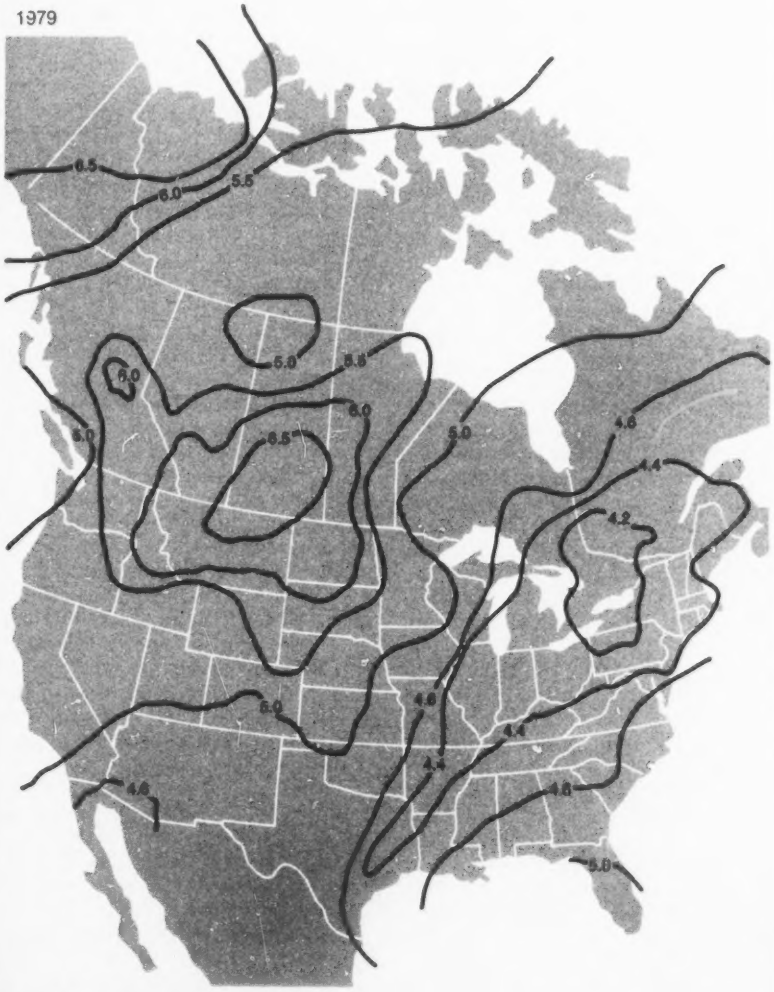
The acid in rain is neutralized by dissolving and mobilizing metals from the soil. Among the metals mobilized is aluminum, which, in combination with high acidity, is toxic to fish. During snow melt, the mobilized aluminum is carried with the runoff to the surface water.

Acidity appears to be spreading southward and westward

Average pH of annual precipitation



Source: C. V. Cogbill and G. E. Likens



Source: National Atmospheric Deposition Program

Carl L. Schofield of Cornell University, who along with colleagues climbed the Adirondacks in 1975 to test the waters of the lakes nestled in the high peaks, was one of the first to note the one-two punch packed by acidified (<pH 5) freshwaters containing high concentrations of aluminum. He also found that aluminum leached by organic acids—those found in naturally occurring acid bog lakes—is complexed in a form that is not toxic to fish. Since his finding, Canadians have documented the lethality of the combination to several species of invertebrates, zooplankton, and aquatic insects. Liken's group at Hubbard Brook is finding similar effects on aquatic invertebrates.

While acid rain is mobilizing from the soil aluminum, which now also can be taken up by plant roots, it is also stripping the soil of the valuable nutrients calcium, magnesium, sodium, and potassium. Nitrogen-fixing bacteria, which live in harmony with certain legumes, are slain by increasing acidity. Other microorganisms that thrive on organic litter and humus also are killed by high acidity; with their deaths, the soil is deprived of an important source of nitrogenous nutrients. Some of this loss, however, can be made up by the sulfates, nitrates, and ammonia in acid rain itself, which are required nutrients.

Because of the fertilizing benefits of the acids, some crops actually thrive in a rain bath of acid, and the harmful long-term effects that acid rain may have on forests now may be masked by this short-term shot of nutrients. The few simulated studies on crops that have been carried out by EPA under unnaturally high doses of acidity are inconclusive, and little field work exists. Under these artificial conditions yields of radish, beet, carrot, and broccoli were reduced. Acid-loving plants like tomatoes thrived. Foliage of spinach and lettuce was damaged and therefore unmarketable, although the yield was unaffected.

Spruce, pine, aspen, and birch are particularly sensitive to enhanced acidity. The protective waxy surfaces of leaves can be stripped, leaving the tree vulnerable to drought and disease; root systems can be damaged by the uptake of toxic metals such as aluminum and perhaps manganese; and transpiration, photosynthesis, and seed germination can be inhibited.

Acid rain, however, is just one of a variety of stresses affecting forest ecosystems. Ozone, sulfur dioxide, nutrient availability, drought, and

Photo by Arne Tollan, Norwegian Institute for Water Research

Trout developing in acidic media die at yolk sac stage. Normal trout fry are at left

heavy metals also "impinge simultaneously on the system," Likens explains. "For whatever reason," Likens says, "the forests in New England appear to be rather unhealthy today."

Canadians are especially concerned about their forests—their number one industry. In eastern Canada alone where the soil is acid, thin, and highly susceptible to acid deposition, the forest industry is worth $4 billion annually and employs thousands of people. In all of Canada, the forest industry employs about 300,000 people, and product exports amounted to $11.5 billion in 1980.

Domtar Inc., the largest forest products firm in Canada, sent George H. Tomlinson to West Germany to review the work of Bernard Ulrich and coworkers. For the past 15 years, Ulrich's group has been studying beech and spruce forests on Solling Plateau, downwind of West Germany's steel and industrial heartland. The West German group has noted serious changes in soil chemistry believed to be triggered by acid rain. These changes are reflected in the serious degradation of the beech and spruce forests. The condition of the beech forest is so serious that no palliative measure, including liming, is expected to save it.

Tomlinson reports that the West German group found that forests act as acid concentrators: Acid reaching the forest floor annually is two (beech) to four (spruce) times the acid in the rain entering the forest canopy. This is so because foliage and bark capture and oxidize sulfur dioxide present in the atmosphere in very low concentrations (dry deposition). The resulting acid is then added to the acid aerosols (very small acid particles) already deposited in the canopy from the air. When it rains both these acid sources are cleansed from the trees and fall to the forest floor.

The increased acid input has slowed the breakdown of humus, and carbon and nitrogen stores in the soil are increasing. The increased nitrogen in the soil undergoes additional reactions that generate more acid, further stressing the trees, mainly by releasing inorganic aluminum into the so-called soil solution. This aluminum is toxic to the fine roots in the soil's mineral layer, and they are damaged. The trees survive though they are severely stressed because the fine rootlets in the humus layer above are less affected by the organically complexed aluminum at that soil level. Although the trees' ultimate survival is in doubt, the West German group recommends liming as a remedial measure to rectify damage done by the altered soil chemistries.

The Scandinavians, who have been monitoring the effects of acid rain longer than anyone else, have yet to discern a decrease in productivity of their forests. Arne Tollan of the Norwegian Institute for Water Research, and one of the authors of the final report of an eight-year-long government-sponsored study of acid rain's effect on forest and fish, says, "There appears to be no serious decrease in forest growth because of the increase in nitrogen deposition accompanying acid precipitation. We are finding an increased leaching of calcium and magnesium in the soils, but at present the fertilizing effects of acid rain are dominant."

Folke Andersson, coordinator of Sweden's research on acid rain's effects on soils, forests, and water, explains that "75% of nitrogen needed by forests comes from the work of soil organisms." Laboratory studies show that increased acidity kills these microorganisms. "Over the long term we ought to see a decrease in forest productivity due to the decrease in organisms releasing nitrogen to the soil. We can't see this yet," Andersson says.

The Norwegian report makes clear beyond a doubt that precipitation in southern Scandinavia has become more acidic as a result of long-range transport of pollutants, and nitrogen oxides are contributing an ever increasing portion to this acidity. Because precipitation forms when air masses rise and cool, the mountainous area of southern Norway has been particularly affected. Here, all lakes in an area of 13,000 sq km are fishless, and an additional 20,000-sq-km area has severely depressed fish populations, Tollan says. The mobilization of aluminum from soils by acid water is cited as a major factor in the reduced fish populations. How altered land-use patterns may contribute to increased acidification and reduced fish stocks is not clarified in the Norwegian study. Nor are any health effects directly attributed to acid waters, although the fear is that acidified drinking water could leach the toxic metal copper from pipes delivering the water to homes. Andersson reports that children in towns along the southwest coast of Sweden, which receive the highest input of acid pollution, have contracted diarrhea from high copper levels in the drinking water. He also reports that fish in some lakes in this area have been declared unfit for human consumption because of high mercury content. There also is speculation that certain concentrations of aluminum and other metals in drinking water may be related to incidences of mental disorders, and that breathing acid sulfate aerosols may result in respiratory and cardiac problems.

U.S. and Canadian scientists came late to the problem—the first recognition that acid rain was falling on the U.S. was by Likens and colleagues in 1970—but they are making up for lost

Death watch at Lake 223

Near the mountain balds of the Adirondacks are hundreds of deep blue, crystal clear lakes. Silent, sterile victims of acid rain. How did these lakes become lifeless?

The Canadians, whose lakes have the same hard granite bedrock as the Adirondack lakes and sometimes receive the same acid pollution, decided to find out. They chose a lake in the so-called Experimental Lakes Area of northwest Ontario, near the town of Kenora.

The 50-acre lake chosen for this unique study has no name, just a number: Lake 223. Its remoteness, 5 miles from the nearest road, had left it pristine, its watershed free of human activity, including logging. Its location, due north of International Falls, Minn., generally had spared it the atmospheric acid onslaught received by those recreational lakes in the southern part of the province and in the Adirondack Park of New York. But Lake 223 is carved from the same low-buffering granite of the Precambrian Laurentian Shield as are the lakes in southern Ontario and upstate New York. It is, therefore, a perfect subject for studying the early chemical and biological changes in an acidifying lake.

In 1974 when the federal Freshwater Institute began studies at Lake 223 its clear greenish waters had a pH of 6.6 and it was teeming with aquatic life. Two years later, in 1976, scientists began to add metal-free liquid sulfuric acid. The first year's addition merely wiped out the lake's alkalinity or buffering capacity without lowering its pH. But from 1977 on, the acid additions, which are equal to the sulfate depositions received by lakes in the Adirondacks, and the Muakoka-Haliburton and Sudbury areas of Ontario in the past 20 years, have lowered the pH 0.25 unit per year. Today, at pH 5.05, Lake 223 is still teeming with life, but startling biological and chemical changes have occurred.

For instance, there has been a slow, steady increase in zinc, iron, manganese, and aluminum—all toxic metals. Since the terrestrial watershed is not being bombarded by acid rain, the leached metals have to be coming from the lake sediments. As yet, phosphorus and nitrogen nutrient species have not changed, and lake productivity measured as chlorophyll production has increased, both findings contrary to Scandinavian experience.

As project leader David W. Schindler explains, the increasing acidity has lightened the color of naturally occurring humic staining materials, thus allowing more sunlight to penetrate deep in the water column where algal blooms are now flourishing. The blooms are expected to die off, however, when the pH drops below 5. With their death, possibly due to the combined effect of low pH and high concentrations of aluminum, productivity of the lake is expected to decline. Also, the nutrient changes noted by the Scandinavians also may begin to appear as the pH falls to 5 or less.

Crayfish bearing infected eggs was taken from Lake 223 (above). Normal eggs are black. Egg mortality in lake has increased severely

To test the combined effects of low pH and high aluminum concentrations, the scientists will begin to add aluminum to the lake, probably by 1983. Until 1983, however, the scientists will continue to unravel the acid-only stress effects. The most surprising of these, Schindler says, have been the biological changes.

So far there has been little effect on the lake trout population, although deformed embryos are becoming more common. The trout's primary food organisms, however, have vanished. Both the fathead minnow and the freshwater shrimp *Mysis relicta* disappeared when the pH fell to 5.8. The fathead minnow was replaced by the previously rare pearl dace minnow.

At pH 5.6 epidemics of attached algae began to appear near the shoreline; lake crayfish, a food organism for trout, began to show stress signs. This invertebrate began to have difficulty in rehardening after a molt and was plagued by parasitic infections. Whether it has become an easier mark for predator trout or victim of increased infection, the crayfish population now has declined a third.

At the present pH of 5.05, zooplankton are "still holding their own or perhaps have even increased a bit," Schindler says. The total number of algal species has not declined, although there have been shifts in species composition. But, for the first time in 16 years, white sucker has failed to reproduce.

Although Schindler's group will continue experimentation at Lake 223 for another five years, it is not likely that it will lower the pH much below 5. The effects below pH 5, when major sport fishes begin to disappear, have been well documented in studies from polluted areas. "Our experiments," Schindler explains, "have been designed to detect the unnoticed early effects, and to assess how these might be eroding the fitness of fish populations by affecting the food web or by placing other stresses on the ecosystem."

time. Acid rain is a growth industry: Every year there are more funds, more research, more scientific reports and more articles in magazines and newspapers. One Canadian scientist facetiously suggests that forests may be stressed more by the demand for paper for reports and articles than by acid from the sky.

Research activities abound in all sectors—federal, state, and provincial governments, universities, and private industries. With the signing of the Memorandum of Intent on Transboundary Air Pollution last August—the first step in negotiating an air quality treaty—five joint U.S.-Canadian research groups are now assessing the current state of knowledge.

Canada will spend $41 million (Canadian) over a four-year period on a coordinated federal effort: Ontario alone spends about $5 million (Canadian) a year on a vast array of atmospheric chemistry and ecological effects studies. President Reagan's budget for fiscal 1982 calls for a 75% increase in funds from $12 million last year to about $20 million in 1982 for the coordinated federal effort mandated under the Acid Precipitation Act of 1980 (Title VII of the Energy Security Act of 1980). Since 1977, the Electric Power Research Institute, the research arm of the electric utility industry, has spent $14.5 million—the single largest research effort on the continent, says EPRI's Ralph Perhac.

EPRI's universe of research includes transport, transformation, and deposition studies, ecological effects efforts, and even projects to develop hardware to collect dry deposited acids, which is a very weak link in understanding the acid rain problem. Perhaps the institute's best-known effort is its three-lake study in the Adirondacks. With EPRI funding ($5.5 million), six universities, Brookhaven National Laboratory, and the U.S. Geological Survey have been conducting "calibrated watershed" studies on three neighboring watersheds, each having its own lake. Similar to the work coordinated by Tom Brydges in Ontario, the EPRI effort is measuring every chemical moiety entering and leaving the watersheds.

Although carved out of the same low-calcium/low-buffering granite bedrock, and receiving the same atmospheric acid onslaught, one lake is very acidic, one is "moderately acidic" (pH 5.5 to 7.0), and the third is not acidic (pH 7). EPRI asks why.

Brydges explains that the glaciers impartially and haphazardly laid down soils, so that although a whole region may be low in alkaline agents, one small area may in fact have a better buffering capacity than another nearby. Also, depth of soil and soil compaction may not be the same from one area to the next. Preliminary data indicate that Brydges is correct.

Indeed, the depth and compaction of the soil around the three lakes differ. EPRI's director of ecological programs Robert W. Brocksen says that the residence time of acids in the soil appears to be an important factor in determining the acidity of the surface waters. Loosely packed soils allow the acid precipitation to percolate slowly, the modifying effect of the soils is enhanced, and less acid eventually reaches the surface waters. He also notes that the increased acidity during snow melt is confined to the top 2 to 3 meters of the lakes.

In an effort to understand how acid rain is formed and what is deposited in lakes, for example, EPA and the Department of Energy sponsored the largest, most comprehensive although inexpensive (about $100,000) set of studies on acid rain. Known as OSCAR (Oxidation & Scavenging Characteristics of April Rain), 100 researchers from six U.S. universities, several national laboratories, Environment Canada, and the Ontario Ministry of Environment converged on the Midwest, downwind of that tight knot of high-polluting coal-burning power plants in the Ohio River Valley, this past April to monitor and collect rain from storm systems.

Stationary samplers were spread throughout 30 states and the province of Ontario to collect deposited rain while an analytical armada of three planes collected samples aloft. Field pH data are now being mapped, but only a fourth of the chemical analyses have been completed because funds have dried up. Still, program director Jeremy (Jake) Hales expects to have most of the results documented by spring 1982 and on computer format by that summer. "Scientists will probably be chewing on this for the next 10 years," Hales says. There are plans to rerun OSCAR in October 1983.

OSCAR was patterned after the Acid Precipitation Experiment (APEX) involving 15 investigators from several universities and atmospheric chemist Al Lazrus of the National Center for Atmospheric Research, who is coordinating the effort. APEX was designed to dissect the chemical sequence of events that create acidity. Lazrus argues that the important but as yet baffling chemistry occurs in the clouds. "Unless one knows what's actually happening in the clouds to produce acids, it is very difficult to regulate. You may regulate something that is very costly and yet will have very little effect on acidity," he says.

From field experiments in which cloud water was collected, APEX data show that "a lot of nitric acid is generated in the cloud, but the mechanism is totally unknown," Lazrus says. Collected samples also show that probably enough hydrogen peroxide vapor is generated in the cloud water itself to act as the rate-limiting oxidant in the transformation of sulfur dioxide to sulfuric acid and possibly nitrogen dioxide to nitric acid.

Hydrogen peroxide precursors—hydrocarbons and ozone—are present in sufficient concentrations in polluted air to generate the oxidant. Lazrus' laboratory work suggests that hydrocarbons are indeed controlling the oxidant level. "We don't know all the processes that give rise to hydrogen peroxide, but we do know that olefins, which are unsaturated hydrocarbons, and ozone are two precursors which are capable of doing this," Lazrus says. He also suspects that there are other mechanisms for generating the acids, but he doesn't know what they are.

Volker Mohnen, director of the Atmospheric Sciences Research Center at the State University of New York, Albany, is a member of the APEX team, and is a coauthor of a National Science Foundation-DOE-sponsored study on "Wet Deposition

Prevailing winds carry acid rain to areas low in natural buffers

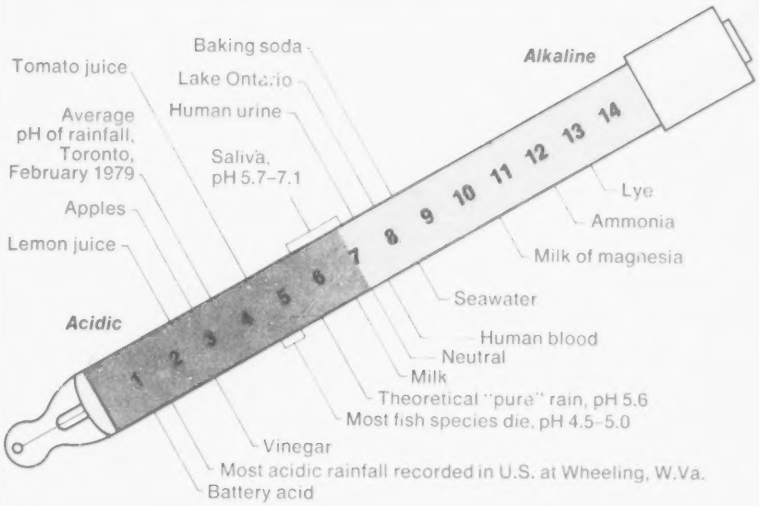
in the Northeastern U.S.," which is being circulated and quoted widely by the coal and electric utility industries.

His group studied the movement of air masses from Canada and from the Southwest and measured and analyzed precipitation falling at a site in Illinois upwind of the Ohio River Valley, and at White Face Mountain in the Adirondacks downwind of the valley. He says the group found no "significant gradient" in wet deposition between the two sites, and that the factor governing the amount of pollution-related ions deposited in rain is the amount of rain, not the direction that the air mass had taken. The rain, however, was less acid in Illinois because of acid-buffering calcium in the Illinois rain. From his work, Mohnen concludes that "it looks as if the acid rain phenomenon is nonlinear with respect to emissions. More emissions do not necessarily mean more acid rain in a proportional way at a specific site." Then he goes on to describe his regional "superbowl," that area from Illinois east, in which high concentrations of sulfur oxides, nitrogen oxides, ozone, and hydrocarbons are emitted from many sources that "somehow ultimately contribute to the acidity of air masses that deposit rain at a particular site." Because of this superbowl, the link between an emitting source and the ultimate deposition site is lost.

He is saying that the question remains which source or sources in the Ohio River Valley to control and by how much to control them to correct the acidity problem in the Adirondacks, for instance. Time is needed, he says, to unravel the chemistry, and to develop better deposition models. "I'm afraid that we will all give our blessing to a 10% reduction in sulfur dioxide emissions that can be achieved through coal washing, scrubbers, and other strategies, and then in five or 10 years look back at the mess and say that it didn't do a darn bit of good. That's dangerous because it hurts the scientific community, and it hurts the overall environmental cause," Mohnen says.

While the research goes on, he suggests that susceptible regions like the Adirondacks be placed in "a holding pattern" by using waterbombers to lime whole watersheds—not just lakes, but the whole shed including forests. He claims that 100,000 acres in Adirondack Park can be limed for a cost of less than $4 million, which includes the establishment of a monitoring network to assure that the cure is not worse than the illness. He admits that Likens views his suggestion as "combating cancer with an aspirin." A Canadian scientist has quipped that "the only agency able to lime all of Ontario is another Ice Age."

Most acidic rainfall in U.S. is more acid than lemon juice



The Canadians offer a different interpretation of Mohnen's findings. Peter Summers, a research scientist with the Federal Atmospheric Environment Service, says that the two sites from which measurements were taken are either in or very near the heavily polluted region from southern Ontario, east of the Mississippi, to the northeastern U.S. Air masses traveling over this region from whatever direction would "reach some sort of saturation," because the pollutants are being deposited out of the atmosphere as fast as they are being accumulated. That's why Mohnen is seeing no gradient, no difference in deposition at the two sites. "There is heavy deposition in the same area having high emission rates. Had he looked outside this region, further west of the Illinois site, for instance, he probably would have seen a gradient," a difference in deposition, Summers believes.

In short, in heavily polluted areas, with many high emissions sources, pollutant deposition is correspondingly high, and independent of wind direction. Outside the polluted area, deposition is highly dependent on wind direction. In relatively remote stations near Kenora, Ont., which is northwest of Lake Superior, "the air is much more polluted when it is coming from the Southeast than when it is coming from the North," Summers says. The Canadians also don't believe that Mohnen has sufficiently considered meteorological conditions that produce rain. How much acid rain is produced depends both on the amount of emissions and on weather conditions, they say.

Gregg Van Volkenburgh, director of the air resources branch of the Ontario Ministry of Environment, agrees with Mohnen that there is not a one-to-one relationship between sulfur dioxide emissions and sulfuric acid formation. He also says that the best strategy over the long term is control of sulfur dioxide, nitrogen oxides, and hydrocarbons. Nevertheless, he says that it is "our feeling that a substantial reduction in sulfur dioxide emissions will lead to a substantial decrease in sulfuric acid in precipitation, and the effect will be seen over a five- to 10-year period." A first step must be taken, and sulfur dioxide reduction is such a step, he contends.

Ontario, he points out, is making its major polluters—Inco with its quarter-mile-high stalk spewing out 1% of the global sulfur budget annually, and Ontario Hydro's four power plants—cut emissions about 50%, "without squandering industry's money." Hiding behind the uncertainties and taking no action is not responsible, Van Volkenburgh says. An accelerated research effort without legislation to begin to deal with the problem would be viewed by Canadians as insufficient. "We are not

asking the U.S. to devise a new regulatory stratagem for acid rain; that's premature," says George Rejhon, environment counsellor with the Canadian Embassy. But, he continues, "We believe that the U.S. ought now, in the course of reviewing the Clean Air Act, to fashion in the law a tool to deal with acid rain."

Under the present Administration, that seems unlikely. The National Acid Precipitation Plan, which was called for under the 1980 Acid Precipitation Act and which is to be the blueprint for a coordinated federal research effort, is expected to be completed this fall. That also is when the actual 10-year research program is to begin, says Chris Bernabo, executive director of the interagency task force developing the plan.

In a June discussion paper on amendments to the law, EPA Administrator Anne M. Gorsuch wrote: "The most conspicuous transport issue is acid rain. Canada is exerting considerable pressure for preventive action. Environmentalists also seek prompt and stern action to address the problem. The best option appears to be to accelerate EPA's current 10-year research project . . . as much as currently available dollars and sound science will permit, and defer regulation until the sources and extent of the problem can be better identified. Industrial groups would support this . . . "

Economics is driving the politics. And like the warm fronts that move eastward across the U.S. to drop acid showers on the Northeast, the hot language of politics is overriding the cold logic of science. Technological controls on the major emitters of sulfur dioxide and nitrogen oxides will be available over the next five to 10 years. But the cost, especially for retrofitting older facilities, would be high. If substantial—on the order of 50%—reduction in emissions were mandated, the power plants also would have to turn to more expensive low-sulfur western coal, depressing the midwestern coal industry and throwing thousands of miners out of jobs. Consumers of electricity in the Midwest would be slapped with substantial rate hikes.

It would be very difficult for President Reagan, who ran on a platform of economic recovery and regulatory relief to industry, to call for strict controls.

So the well-organized voices of the coal and electric power industries have been heard and heeded. Conoco's William C. Hamilton: "Our argument is that it would be a very chancy thing to come out with regulations aimed at decreasing the acidity of rainfall that were based on the supposition that if you dropped sulfur dioxide emissions 50% it would produce a 50% reduction in acidity. We don't think that follows at all. Our fear would be that there would be a very large amount of economic disruption, at great cost to the consumer, and quite possibly very little relief from the acidity of rainfall."

Electric Edison Institute's Jack Taylor: "Information doesn't exist on the extent of damage, on the causes, and on the transport/transformation mechanisms that contribute to acid rain. At this time, not enough is known to set prudent public policy. We think an aggressive research program should be undertaken in order to answer these questions."

Kathleen M. Bennett, EPA assistant administrator for air, noise, and radiation: "When the Administrator [Gorsuch] had the press conference which reported the principles agreed to [on the Clean Air Act], there was a principle which said that research on acid deposition should be accelerated. It seems clear to us that there are so many questions of a very basic nature that remain to be answered that it would be inappropriate for us to ask the American public for $20 million for research this year and more in the next five or 10 years but then say, 'By the way, here's a regulatory scheme which purports to know the answers to the questions we are now asking you to fund.'"

Though that appears to be the Administration's position on acid rain now, it already has considerably moderated its general stance on revisions to the Clean Air Act, and may do so again on this issue. During his campaign, Reagan found the Clean Air Act an onerous law in need of drastic modifications. Then a couple of months ago a Harris Poll was released showing that 86% of the public fully supported clean air legislation. Reagan backed away from the fray, and sent the EPA Administrator out to announce not proposals with legislative language but 11 principles on needed revisions. She did so while Congress was in recess, and Congressional staffs were busy drafting clean air bills.

Mitchell: Acid rain amendment offered

If Canada maintains pressure on the Administration, especially if it comes from Prime Minister Pierre Trudeau, and if Americans across the U.S., not just those in affected states, can be made aware of the issue, then there is a possibility that the issue will be addressed in a renewed Clean Air Act or through separate legislation. Republican Robert T. Stafford, chairman of the Environment Committee and Senator from the acid-drenched state of Vermont, told C&EN that he would "try to pass legislation affecting the acid rain question in this Congress." But, he added, "I think the Clean Air Act is a ship that is going to be carrying a full load of cargo by itself. I don't intend to stick an acid rain cargo on top of the cargo that is already there and cause the ship to sink. So if it looks as though acid rain legislation would overload the Clean Air Act, it's not going to go on it, as far as I'm concerned. It will have to come up as a separate piece of legislation.

Sen. George Mitchell (D.-Me.), who sits on the Environment Committee, plans to test the stability of the ship. This week he will introduce an amendment to the air law that would provide for an inventory of existing sulfur dioxide emissions in a region from Tennessee north and from Illinois east, prohibit further increases in total levels of emissions, and mandate a reduction in emissions over a 10-year period. The House is further away from writing a bill, but Rep. Henry A. Waxman (D.-Calif.), chairman of the Health & Environment Subcommittee, has called acid rain a threat to the nation's air, waterways, water supplies, and forests that also jeopardizes U.S. relations with Canada. "The time has come to cut back on the air pollutants that cause this destruction," he says.

Canadians understand that increased public awareness and sensitivity to the issue will most likely

translate to increased pressure on members of Congress to take some action. To this end, government officials and especially Environment Minister John Roberts speak on the issue at every opportunity. On a less official level, a Canadian coalition of 22 special interest groups whose members number 1.5 million has opened an office in Washington, D.C., to complement its Toronto-based activities. Adele Hurley runs the Washington operation of the Canadian Acid Rain Coalition. From this platform she informs "the American public of the grave implications that emissions from the U.S. are having on the Canadian environment."

The political concern in Canada already is at very high official levels. When Prime Minister Trudeau met with President Reagan in Washington on July 10 in preparation for the Ottawa economic summit meeting, "the only bilateral issue they discussed was acid rain," reports deputy assistant minister of the environment Raymond M. Robinson. Still, Robinson says that his government does not intend to pressure the U.S. government into action by linking energy exports to the acid rain issue. Nevertheless, Canadian environmental groups have called for just such a linkage.

The Canadian government, however, is not reluctant to remind the U.S. of the mutual obligations incurred from the mechanisms that have evolved over the years to resolve problems common to both countries: Principle 21 of the 1972 Stockholm Declaration; the Boundary Waters Treaty of 1909, an arbitral tribunal ruling in the 1930's against a British Columbian smelter for damages caused in Washington state, and the Great Lakes Water Quality Agreement of 1972.

The situation that resulted in the 1972 water quality treaty is similar to the acid rain problem today. Then there was imperfect understanding of the effects of phosphorus on the Great Lakes. Today it is not possible to relate emissions from a particular plant to dead fish in a particular lake. Nonetheless, Roger Simmons, a member of Parliament, says, "We cannot wait for a perfect understanding of the acid rain phenomenon before moving to control it. If we had waited back in 1972 for a complete understanding of the effects of phosphorus on the Great Lakes before starting our joint cleanup program, we would still be waiting and Lake Erie would be irreversibly dead."

C&EN staff photo

Stafford: Clean Air Act overload

Robinson calls the lack of a precise source-receptor relationship a "dead herring." He says that "if you are going to reduce the total burden to the atmosphere of sulfur dioxide on a cost-effective basis, which means controlling the biggest sources most thoroughly, then you are going to reduce the amount of sulfur available to turn into sulfate. It is as simple as that, and all the rest is just a pile of garbage designed to cloud the issue."

The cost to control sulfur emissions, however, is staggering. According to DOE's Jim Bartis, an internal study estimates that to reduce emissions permanently 3% or 1 million tons per year in the utility sector alone would cost about $2 billion in 1981 dollars. Beyond that incremental reduction, the cost rises rapidly, he says. To reduce emissions a significant amount—5 million to 10 million tons per year—would cost $5 billion to $7 billion.

Earlier, EPA estimated that a 10 to 30% reduction in sulfur dioxide emissions in the utility sector would cost $1 billion, and raise utility customer bills 2 to 3% per year on a national average. Customers in the Ohio River Valley, however, would be socked with rate hikes of 10 to 15% per year. EPA's Lowell Smith has suggested a possible "redistribution of revenues collected from all electricity users in the country for use in areas where emission control and/or acid precipitation is the greatest problem."

On the other hand, a recent National Academy of Sciences report, "Prevention of Significant Deterioration of Air Quality," pegs the damage costs in the eastern third of the U.S. in 1978 at $5 billion. This includes damage to materials, forest ecosystems, agriculture, aquatic ecosystems, and health and water supply systems. The New England River Basins Commission estimates current economic losses in the New England/Adirondack region of New York from acidic deposition at $250 million to $500 million per year, exclusive of harm to health. And Fredric Menz, an economist at Clarkson College, says a preliminary estimate of the economic losses from the acidification of Adirondack lakes is "$1.6 million to $6.4 million annually in loss of value to New York anglers, and a regional economic impact resulting in a reduction in expenditures by New York resident anglers of $875,000 to $1.75 million annually." Out-of-state and nonlicensed anglers are excluded from the estimates.

The economic damages may be even greater for Canada, a smaller nation. Gross angler expenditures and investments were just over $1 billion in 1975. This is in jeopardy. In Nova Scotia, 30% of the salmon potential is threatened. High acidity threatens the nation's boreal forests. This resource provides employment for more than 10% of the Canadian labor force.

Canadian Environment Minister Roberts says that "Canada expects the U.S. to recognize that it must internalize the real costs of those activities, especially thermal power generation, which produce acid-causing pollutants, rather than exporting those costs across the border in the form of environmental damage to us. By any reasonable interpretation of existing international legal principles the U.S. cannot continue to derive significant economic benefits by exporting significant 'disbenefits' to Canada, particularly when the technology exists to prevent this from happening."

If the Canadian claims are correct—and a just-released National Academy of Sciences study of the problem says they are—power plants burning coal and oil and emitting sulfur and nitrogen oxides are responsible for acid rain. If the Canadians' timetable is correct, that nation will be experiencing ecological and economic disaster before the turn of the century. In view of the potential cost to Canada, the coal and electric utility industries' apparently successful campaign to thwart legislative efforts to control acid rain may be a Pyrrhic victory. □

explains Eschenmoser, that despite their apparent complexity, they readily form by themselves, provided the necessary precursor molecules are available.

Eschenmoser and his coworkers also are investigating other corrinoid structural features that may have "autogeneous character."

All natural porphyrinoids, as well as vitamin B_{12}, are known to be biosynthesized from one particular isomer of a tetrapyrrolic macrocycle called uroporphyrinogen. Living organisms such as bacteria can assemble this uroporphyrinogen isomer from a simple monopyrrolic precursor. Moreover, Mauzerall and others have shown that this same precursor can be converted easily to a mixture of four uroporphyrinogen isomers under simple chemical conditions—conditions that might have existed on primeval Earth. Of these four isomers, the one that forms in the greatest amount turns out to be the one of biological importance. This coincidence may not be accidental, according to Eschenmoser and other scientists. It is possible, he suggests, that the statistically preferred isomer—the one formed in largest amount in an abiotic environment—may have been "selected to become biosynthesized" after organisms found uroporphyrinogens to be biologically "useful and important for survival." These rudimentary organisms may simply have chosen the uroporphyrinogen isomer that was most abundant, and incorporated it into their biochemistry. □

Studies of cancer risk in chemists assessed

1981 ACS ANNUAL MEETING

Various epidemiological studies over the past dozen years have been probing the connection between the occupation of chemist and the risk of cancer. Now studies are being made and existing ones are being extended and expanded. But as yet very little in the way of a conclusion can be drawn from them.

Shelia K. Hoar of the environmental epidemiology branch of the National Cancer Institute sums up the current situation: "We can conclude that there are some excess risks associated with the occupation of chemist. At this point, we cannot differentiate between effects of chemical exposures and socioeconomic or other factors related to being a chemist."

Swedish mortality study finds chemists show excess of leukemias/lymphomas and brain tumors

Cause of death	Chemists		Mining engineers/ metallurgists		Architects	
	Observed	Expected	Observed	Expected	Observed	Expected
All causes	83	103.8	49	74.9	59	87.8
All cancer	32	24.2	17	17.5	11	20.5
Digestive	8	9.2	4	6.7	3	7.9
Pancreatic	2	1.6	0	1.1	2	1.4
Respiratory	3	4.0	4	3.6	5	3.4
Prostatic	3	1.5	0	1.1	1	1.4
Urinary	3	1.8	2	1.2	0	1.5
Brain	5	1.2	2	0.9	1	1.0
Lymphatic/hematopoietic	7	3.2	2	2.3	0	2.7
Hodgkin's	3	0.7	0	0.5	0	0.5
Circulatory	22	40.4	10	29.5	20	35.1
Accidents	15	21.9	16	15.5	15	17.6
Other causes	14	17.3	6	12.4	13	14.6

Hoar discussed the studies for the Division of Chemical Health & Safety. Included was a recent study of her own, conducted with Sidney Pell of the epidemiology section in the medical division at Du Pont, Wilmington. That effort was a retrospective cohort study of mortality and cancer incidence among men and women employed at Du Pont as chemists in 1959 (C&EN, Aug. 17, page 34).

All told there have been eight studies, including the Du Pont one. The other seven:

- Death certificates of some 3600 members of the American Chemical Society whose deaths were reported in C&EN from 1948 to 1967 were examined in 1969 by epidemiologists from the National Cancer Institute.
- A study of occupational mortality in the state of Washington from 1950 to 1971 included chemists.
- There was a similar study of occupational mortality in the state of California from 1959 to 1961.
- In Sweden, a retrospective cohort study was made of mortality among graduates during three decades from two Swedish schools of chemical engineering.
- Registrar General's occupational mortality study in England and Wales in 1970 to 1972 included chemists.
- Also from Great Britain, preliminary reports were made of a proportional mortality study of 938 deceased members of the Royal Institute of Chemistry.
- A study of mortality by occupation level and cause of death among men 20 to 64 years of age in the U.S. in 1950 included chemists.

Together, the studies suggest that excess cancer risk is associated with the occupation of chemist. But, Hoar notes, all eight studies have their strengths and weaknesses.

For example, professional chemist societies include both persons heavily exposed to a wide variety of chemicals and persons with little or no chemical exposure. Occupations given on death certificates are often inaccurate. Several of the studies are based on proportional mortality rates, which can appear elevated as a result of deficits in other causes of death. Also, some studies are based on small numbers.

Thus, Hoar says, little can be concluded from any study alone. Still, she says, when all eight studies are considered, patterns in the morbidity and mortality data become apparent.

The studies show that chemists generally have lower mortality overall and lower mortality due to lung cancer. Half the studies show excess mortality for all cancers combined, half do not.

Lymphatic and hematopoietic cancers (leukemia), colon cancer, cerebrovascular disease, and suicide occur more frequently than expected in most of the studies. The studies, Hoar notes, have very sparse data for bladder cancer, a site often associated with chemicals. The two reports that have data for the disease show that bladder cancer occurs more frequently among chemists.

Hoar points out that better expo-

sure histories are needed to determine the factors responsible for the associations seen in the chemist studies. When more time has elapsed, she suggests, and additional subjects have developed illnesses and died, the Du Pont data could be reanalyzed by department and process. Efforts should be made, she says, to characterize occupational exposures beyond job title and department affiliation through industrial hygiene data.

One effort that continues is the Swedish study, first published in 1976 (*Lancet*, **7991**, 916 (1976)]. The study is being carried out by G. Robert Olin, director of the occupational health and safety department at the pharmaceutical firm Astra Inc., Södertälje, Sweden, and a professor in the preventive occupational medicine unit in the department of heat technology at the Royal Institute of Technology, Stockholm.

Olin told the Division of Chemical Health & Safety that since the original study appeared it has been expanded in several ways. The original cohort, he says, has been widened and the followup period lengthened. The original study was of chemistry graduates for three decades—1930's, 1940's, and 1950's—from the Royal Institute of Technology.

Olin now has included two other academic cohorts for comparison. The first consists of architects, a group of academics who have been educated in the same city, the same university, during the same period of time, and who can generally be considered to belong to the same social strata as the chemists. The only apparent difference between the two groups, Olin explains, is the chemical exposure that occurred among all chemists, at least during their four or five years of education.

The second additional cohort consists of male mining engineers and metallurgists, who also were educated at the Royal Institute of Technology. The idea behind including this group is that it holds an intermediate position in relation to chemical exposure, at least during the education years.

The total number of chemists involved from the three decades is 820. To this now have been added data for 581 mining engineers/metallurgists and 657 architects.

Besides adding the two groups to the study, Olin has extended and analyzed data from a followup to the study until the end of 1977.

Olin points out the "very positive results" occurring among the cohorts. For all three, the total mortality is low relative to the general population and there is no significant difference between them. The main explanation, he says, seems to be a lowered rate of deaths due to circulatory diseases—a particularly interesting finding, he notes, since it has been believed until recently that the higher social classes in industrial societies were more prone to circulatory diseases.

As for cancer mortality, it accounts for a fifth of the deaths among the architects—identical to the proportion found in the general population. For chemists, however, the cancer rate is higher in comparison to the general population and significantly higher in comparison to the architects. Mining engineers fall between the two groups and their cancer rate is significantly elevated when compared to the architects.

Olin notes that there is no increase of lung cancers in any of the three cohorts, thus diminishing the possibility that smoking could be the major explanation for the differences among them.

Among the mining engineers and metallurgists, there is no single cancer type that can account for the increase in cancer cases, relative to those of the architects. However, among the chemists two types of malignancies account for most of the relative increase of cancer deaths: leukemias/lymphomas and brain tumors.

Olin says that preliminary data for 1978 and 1979 are now available. During these two years, 13 more chemists have died, four from cancer. One of these cancer cases was glioma, bringing the total among the cohorts to six. And one death was due to a leukemia, bringing the total to eight.

The followup of the three cohorts is continuing, Olin says. During 1977 and 1978, the surviving chemists answered retrospective questions concerning life habits and chemical exposure. The participation rate was an acceptable 85%, Olin says, so there is the possibility for a better evaluation in the future of the relationship between life style, or chemical exposure, and various causes of death. □

Lanthanide, actinide organometallics studied

1981 ACS ANNUAL MEETING

The organometallic chemistry of the lanthanide and actinide group elements is under study in many different laboratories. New information about how these elements interact with organic molecules and the potential chemical applications for these interactions was presented in several different sessions of the Inorganic Chemistry Division.

Roger E. Cramer, chemistry professor at the University of Hawaii, Manoa, for example, described the organouranium complexes he and colleagues have prepared. These researchers have been studying uranium phosphoylide complexes for several years, and now have prepared one of these complexes, $(\eta^5\text{-}C_5H_5)\text{-}UCHP(CH_3)_2(C_6H_5)$, with a carbon-uranium bond so short (2.29 Å) that it should be considered a multiple bond. Complexes with multiple carbon-metal bonds, called alkylidenes, are known for many transition metals, though they are not common, Cramer points out. Their compound is the first alkylidene of an actinide element to be observed.

The chemists have begun to investigate how similar the chemistry of their uranium alkylidene complex is to that of better-studied transition metal alkylidenes. They find, not unexpectedly, that the uranium-carbon bond is a very reactive one. For instance, carbon monoxide can insert into this bond under mild reaction conditions. (In toluene solution, the reaction can occur at 25 °C and 1 atm pressure of carbon monoxide.) Similar insertion reactions have been seen for alkylidenes of zirconium and tantalum, Cramer says.

The Hawaii chemists have other evidence of the reactivity of the carbon-uranium bond in their compound: It reacts with methyl iodide to produce an organouranium iodide salt and a phosphonium salt, and it reacts with other halogens, including halocarbons. The other organouranium complexes that the group has investigated—those that contain carbon-uranium single bonds—do not react with halocarbons. The uranium alkylidene complex also reacts with carbon dioxide, stannous chloride, and several other mild reagents.

Another group studying the organometallic chemical reactions of organoactinide complexes is that of Tobin J. Marks, Robert L. Burwell Jr., and associates at Northwestern University. This group has been investigating the effect of supporting

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September 21, 1981

Candidates in ACS fall election
Their views and backgrounds Page 24

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Chemical & Engineering NEWS

Cover: False-color image of Saturn's C-ring (blue) and B-ring (golden) made from three pictures taken through separate filters from Voyager 2 from a range of 1.7 million miles. Photo courtesy of NASA

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News of the Week

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- ***University of California plant geneticist*** *who also is officer of a biotechnology firm barred from receiving industry grant on basis of conflict of interest.* ***Page 7***
- ***"Yellow rain" showers*** *that afflicted villagers in Afghanistan and Southeast Asia contained toxins of the trichothecene family, the State Department says.* ***Page 7***
- ***Exxon's $15 million engineering education grant*** *to encourage students to take graduate degrees and enter teaching is aimed at alleviating shortage of instructors.* ***Page 8***
- ***University scientists and engineers*** *spend one third of their time in research, one third in teaching or teaching-related activities, NSF survey shows.* ***Page 8***

Business

- ***Chemical stock prices have fallen sharply,*** *C&EN's stock index indicates, after performing well for the first six months of this year.* ***Page 10***

International

- ***Chemists soon will be able to join IUPAC*** *on an individual basis under an affiliate plan accepted by the union at its recent meeting in Belgium.* ***Page 11***

Government

- ***Power plants are big sources of acid rain*** *via the burning of fossil fuels, according to a recently released report by the National Research Council.* ***Page 14***
- ***Numerous bills to stimulate innovation*** *and productivity have been passed by the New York State Assembly in its 1981 high-technology/ R&D program.* ***Page 15***

Science Policy

- ***Director of "Limits to Growth" study*** *Dennis Meadows heads Resource Policy Center at Dartmouth engineering school, where computerized modeling techniques are applied to wide range of global issues.* ***Page 16***

Science

- ***Theories explaining dynamics of Saturn*** *and its rings and moons are being revamped in light of new data received from Voyager 2's closer approach, more efficient cameras, and photopolarimeter experiments.* ***Page 19***
- ***Analgesic more potent than morphine*** *draws its design from the active ingredients of marijuana, report chemists from Pfizer central research.* ***Page 23***

ACS Election

- ***Candidates for 1982 president-elect,*** *two director-at-large vacancies, and directors of Region III and Region VI give their views on society affairs.* ***Page 24***

Chemical stock prices have moved down sharply

After performing well earlier this year and staying up longer than other indicators, C&EN stock index dropped some 20% since June

Continuing high interest rates, worries over the money supply, and uncertainties about the government's economic programs continue to plague the stock market. As a result stock market indicators are at their lowest levels in more than a year.

And chemical stocks are joining them. For the first six months of this year, chemical stocks performed well. But all of this has been more than wiped out in the past three months as chemical stocks, along with just about every other type of stock, took a dive.

C&EN's stock price index climbed to a high of 250 (1954 = 100) on June 12. Since then it has fallen more than 20% to 206 on Sept. 11. The C&EN stock price index is a weighted index based on the stock prices of seven leading chemical companies—Allied Corp., American Cyanamid, Celanese, Dow Chemical, Du Pont, Monsanto, and Union Carbide.

However, C&EN's index climbed more steadily and stayed up longer than other, more general indicators. The widely quoted Dow Jones Industrial average peaked April 30 at 1024 and then began its jagged erosion to about 873 on Sept. 11, 14.8% below its high just a few months earlier.

Standard & Poor's 400 Industrials had peaked even earlier than the Dow Jones, hitting 161 on Nov. 28, 1980. From there it fell, rose again, tapered off through the spring and summer, and fell drastically in the past month. Thus, by Sept. 11, it was 15.1% below its high.

In spite of the much slower and higher climb for chemical stocks than for other indexes, when the C&EN index started to drop it fell faster and farther than the other indicators. While the Dow Jones was dropping 14.8% in about five months and Standard & Poor's Industrials 15.1% from its high in 10 months, the C&EN chemical stock index was falling more than 20% from its high in just three months.

Further, the C&EN index is 7% below its level a year ago, the same percentage drop as the Dow Jones. The Standard & Poor's Industrials average is just 3% under its year-ago level. It is still to early to tell, but one has to wonder if the rise and fall of the chemical stocks in the past year may be a precursor of a pattern similar to that of the mid-1970's.

During the 1975 recession and for a little time thereafter, chemical stocks were looked on with high favor by Wall Street. This attitude had faded by mid-1976, driving chemical stock prices down to a level where they would languish for three years.

The situation this time around is uncomfortably like 1976. Capacity use is low, many prices are discounted, and inventories are rising. This is what Wall Street may be anticipating—a long, drawn out recovery or possibly another profits downturn.

Of the companies making up the C&EN index, three had higher stock prices on Sept. 11 than they had a year ago. Monsanto was the star performer, selling at $66.25 per share, a 29% gain from a year ago. Union Carbide stock was selling at $49.25, 10.4% higher than a year ago. And Celanese stock was up 6.7% to $26.625 per share.

The remaining four firms' stock prices are lower than a year ago. Dow Chemical stock at $28.125 was off 21.6%; Allied Corp. $45.375, off 11.2%; Du Pont $40, off 10.4%; and American Cyanamid $26.625, off 4.1%.

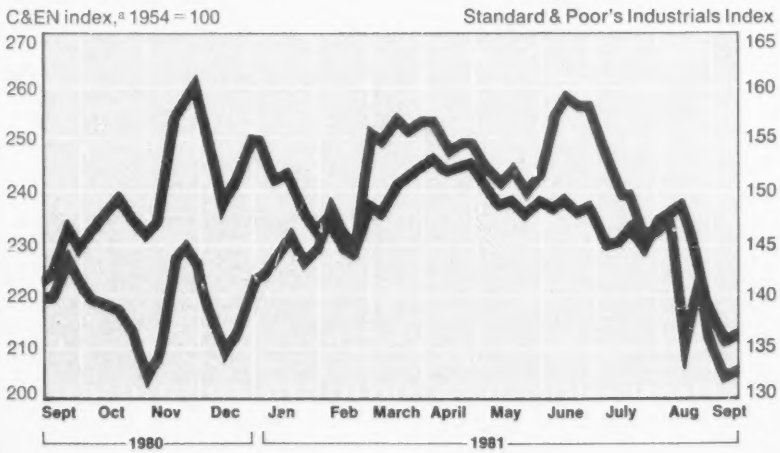
The biggest drop from a 12-month high was Du Pont, whose stock price was 28.6% below its peak of $56. This was followed by a 27.9% drop from $39 for Dow, 27.1% from $36.50 for American Cyanamid, 26.5% from $51.125 for Allied Corp., 24.3% from $87.50 for Monsanto, 20.7% from $62.125 for Union Carbide, and 16.8% from $69.25 for Celanese.

William Storck, New York

Chemical stocks index dropping more than most

	Sept. 11, 1981	Sept. 12, 1980	% change
C&EN chemical stock index	206	221	−7%
Dow Jones Industrial Average	873	937	−7
Standard & Poor's 500 Composite	122	126	−3
New York Stock Exchange Composite	70	73	−3
American Stock Exchange Index	331	341	−3
Over the Counter Composite	190	190	0

Chemical stocks have lost more than 20% since their high



a C&EN index based on stock prices for Allied Corp., American Cyanamid, Celanese, Dow Chemical, Du Pont, Monsanto, and Union Carbide.

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Richard Garwin, government adviser, analyzes the arms race
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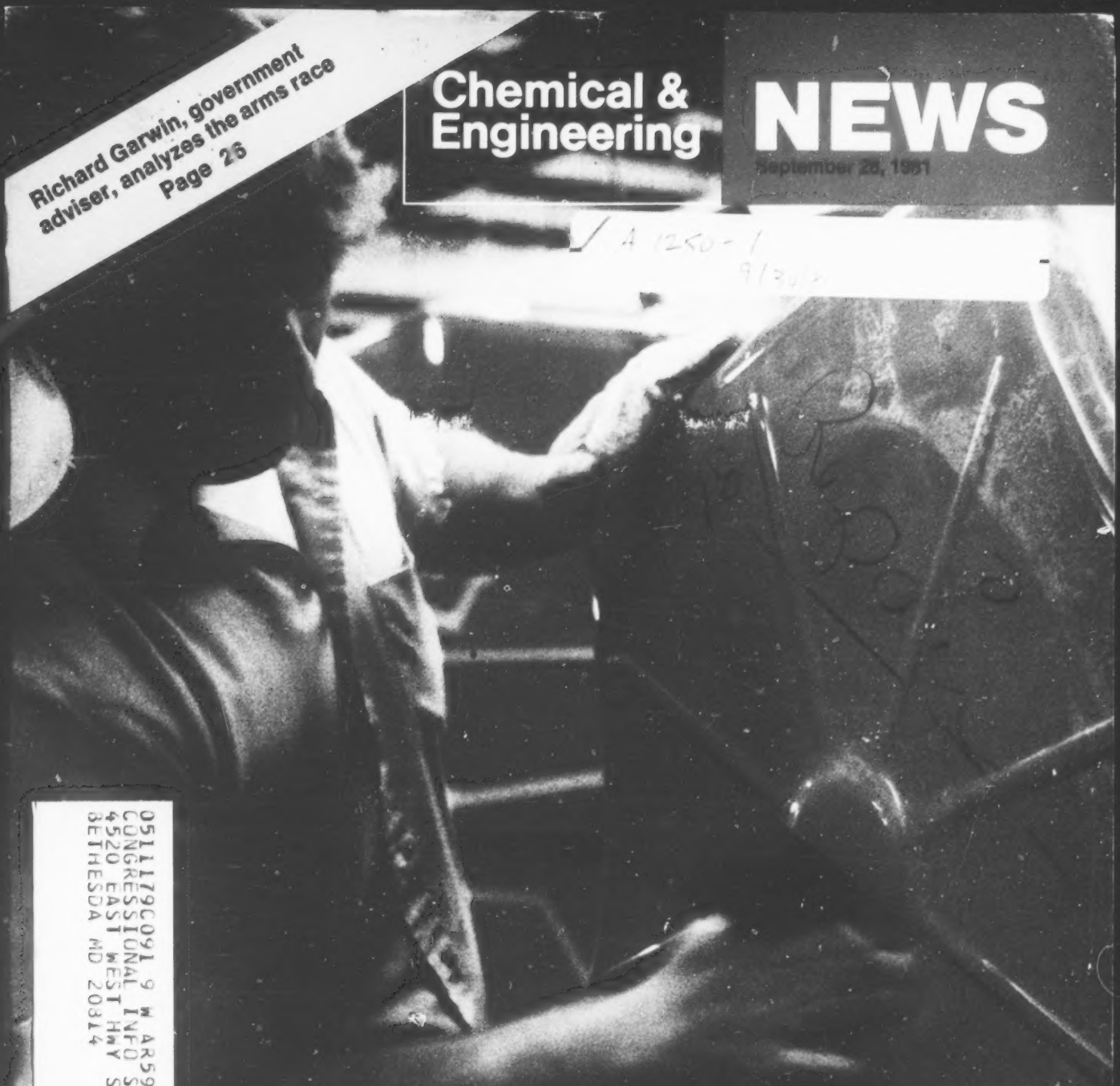

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Thermoset plastics

Fresh downturn feared

A Key Polymers Review

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Chemical & Engineering NEWS

Cover: Worker polishes reinforced polyester bathtub assembly. Photo courtesy of Owens-Corning Fiberglas

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- ***Sales of thermoset polyesters and epoxies*** *are not expected to improve soon; phenolics and amino resins may suffer further declines until economy improves.* ***Page 15***

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Books

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Thermoset plastics recovery turns shaky

New drops in housing starts, durable goods sales may mean no improvement for polyesters and epoxies, and further losses for phenolics

Economists may be divided about whether a new recession in the U.S. economy started in the second quarter of this year. There is no doubt among thermoset resin producers, however, that they are entering the second year of their own private recession.

Continued high inflation and interest rates have escalated prices of houses, cars, appliances, and all the other durable goods on which thermosets depend, as well as costs of loans to buy them. Though inflation may have abated, interest rates have fluctuated for three years between two values: too high and higher than that. Thus the best that epoxy and unsaturated polyester producers can hope for may be that they can hold 1981 sales level with those of 1980, which themselves were depressed. Producers of the other two major thermosets, phenolic and urea-formaldehyde resins, may see further declines of 10%.

Thermoset sales may not improve much in 1982 either. Though inflation may ease, prices of durable goods will be stuck at high levels. Too, declines in real prices of houses, caused by sellers' acceptances of mortgages at lower than market rates, may tarnish the reputation of houses as inflation-proof investments. Thus after a sluggish recovery in the second half of 1982, thermoset resin producers may have to wait till 1983 for a "normal" recovery.

Such a sales performance simply would be repeating history for thermosets, though. Producers had to wait out a relatively flat year after the recessions of 1970–71 and 1974–75, and they may have to do it again.

Epoxy resins have shown once again that they are relatively resistant to recessions. This is because of their broad base of applications and because manufacturers specify them for high-performance applications, especially protective coatings. According to the Society of the Plastics Industry's committee on resin statistics, whose figures are compiled by Ernst & Whinney, total epoxy sales dropped only 6% in 1980 to 319 million lb. This decline followed a 5% gain in 1979 over 1978. U.S. sales may remain flat in 1981, while a decline in exports could lower total sales to 310 million lb.

Polyesters, whose sales are more mercurial owing to heavy dependence on marine and transportation markets, continued to decline in 1980, dropping 18% to 950 million lb, following a loss of 4% in 1979 compared to 1978. There may be no change in 1981.

Phenolic resins sales posted a drop of 12% in 1980 to 1.35 billion lb, more than offsetting the 12% gain in 1979 over 1978. Sales may be down another 10% in 1981 because of the heavy dependence of these resins on construction. C&EN reports lower phenolics production and sales figures than those of SPI owing to subtraction of an estimate for fillers in molding compounds. SPI has changed the format for reporting monthly phenolics sales, so it is not possible to follow 1981 trends in detail in comparison to 1980.

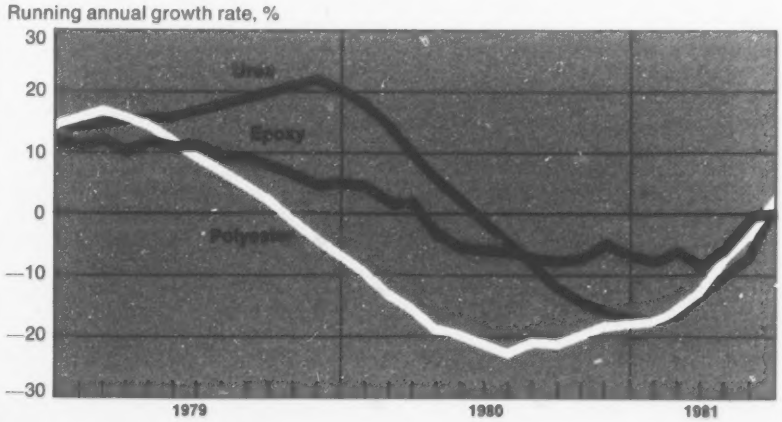
Nevertheless, it is possible to get indirect information on phenolics from urea-formaldehyde resin data. More than three fourths of phenolic and of urea-formaldehyde resins each go for adhesive and bonding applications. Sales of urea-formaldehyde resins hit bottom in February 1981 when they were dropping at an annual rate of 17%. Phenolics' sales bottomed out at a 13% annual decline in October and November 1980. By July 1981, urea-formaldehyde had started to grow again, at a rate of 3% per year, and phenolics also may have done so. Renewed downturns in building construction may produce 10% net losses in resin sales for the year, however.

Part of the reason for the beating thermoset sales are taking has been the high interest rates on mortgages and consumer and business loans. The prime lending rate (the rate banks charge their most favored customers) has exceeded 11% for more than two years, and topped 17% for more than a year.

For now, the housing market continues down, with housing starts possibly dropping 30% to 1 million in 1981, following a 14% fall in 1980 compared to 1979. For automobiles, new car sales could rise 9% this year to 7 million, which would not nearly make up for the 24% plunge in 1980 compared with 1979. With the continued exception of epoxies, the sales picture for thermoset resins thus will continue grim.

Steve Stinson, New York

Sales growth recovered earlier in 1981



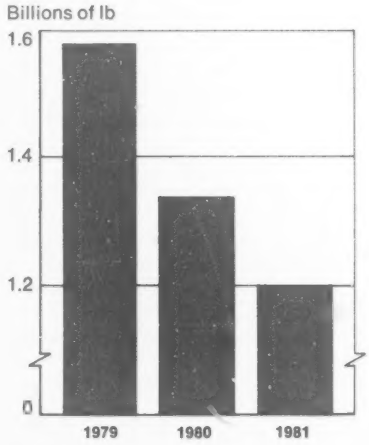
Source: Society of the Plastics Industry

Key Polymers

Phenolics

- ***Posted prices up***
- ***Capacity ample***
- ***Markets sagging***

PRODUCTION



HOW MADE

Condensation of phenol and formaldehyde. One-stage products cured by heating; two-stage products cured by heating with hexamethylenetetramine

MAJOR END USES

Plywood 35%, glass-fiber insulation 21%, molding compounds 7%, laminates 7%, fibrous and granulated wood 7%, foundry core binders 6%

FOREIGN TRADE

Exports—2% of total sales, imports—negligible

PRICES

48 cents per lb, 100% solids basis

COMMERCIAL VALUE

$575 million for total production, 1981

The long-running sales slide for U.S. phenolics, among the most mature of thermoset resins, began in midsummer 1979 and may have hit bottom only temporarily in October 1980. Figures of the Society of the Plastics Industry's committee on resin statistics, compiled by Ernst & Whinney, show a sales loss of 12% from 1979 to 1.5 billion lb in 1980. Sales are likely to be off another 10% in 1981 to 1.35 billion lb, smacked by renewed declines in auto sales, construction, and other industrial markets.

About 85% of phenolic resins go into adhesive and bonding applications, largely in very cyclical durables industries. For example, about 470 million lb of phenolic resins went into plywood in 1980, 285 million lb in binders in glass-fiber insulation, almost 100 million lb in laminates, and 95 million lb in particleboard. In automotive and general manufacturing, 77 million lb went into foundry core binder for metal casting. Phenolic molding compound for plastic parts consumed almost 100 million lb of resin to make 245 million lb of finished compound.

Sales of molding compounds dropped 20% in 1980 from 310 million lb in 1979. Molding compound losses began to ease in October 1980 along with those in other phenolic resin applications. Growth on a running annual rate basis had almost begun to resume in August 1981. However, observers ascribe this turnaround in phenolics markets to depletion of customer inventories and resumption of orders rather than to any strengthening of end uses themselves. Thus the last half of this year is likely to see renewed deterioration of sales in almost all categories.

The only bright spot for phenolics has been glass-fiber insulation binder, which has remained flat at 285 million lb throughout.

Hardest hit among phenolics markets were foundry core binders. These suffered a 32% loss in sales in 1980, and further severe slippage is expected in 1981.

Getting a good statistical picture of phenolic resin sales in this crucial time of partial recovery and renewed decline is especially difficult. The reason is that SPI changed its reporting format in January 1981 from a purely resin to a gross weight basis. Because products for various applications range from 25 to 100% resin, the change makes 1981 data incommensurable with 1980.

To arrive at its own production figures, C&EN has used SPI data, subtracted an estimate for fillers in molding compounds, and come up with 1.58 billion lb in 1979, 1.34 billion lb in 1980, and 1.2 billion lb in 1981.

Plant capacity also is impossible to pin down for phenolics, which are made by dozens of companies, many of whom do not consider themselves to be in the plastics industry. However, capacity is described as more than adequate and cheap to install if needed.

Increased raw material oil and gas prices resulted in an increase in the average price of 100% phenolic resin to 45 cents per lb this year from 37 cents in 1980. Producers have raised prices in 1981 to 48 or 49 cents, but market conditions make it uncertain that this rise will stick.

On the regulatory scene, phenolics used in plywood and particleboard are involved in the controversy over alleged carcinogenicity of formaldehyde through vapor emissions from finished boardstock in, for example, mobile homes. One possibility is that phenolics actually might benefit by taking over the almost 1-billion-lb urea-formaldehyde resin market in plywood and particleboard. A study by Booz-Allen & Hamilton for the Formaldehyde Institute estimated that such a move would result in a $400 million to $500 million annual increase in building materials costs, following a one-time capital outlay of $350 million to $700 million by building products producers.

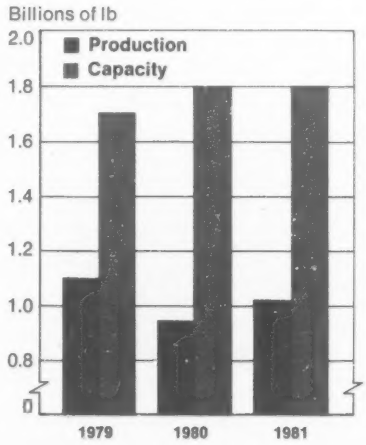
Another possibility is that phenolics could be banned totally from plywood and particleboard. The replacement could be polymeric isocyanates, at a $1 billion annual increase in prices, following $1 billion in initial capital costs, according to Booz-Allen. Though the chief concern to date of phenolic and urea-formaldehyde resin producers in the formaldehyde issue has been action by the Consumer Product Safety Commission, individual states also have introduced legislation and regulations on such building materials. Thus the issue might have to be fought out in 50 states even if CPSC stays its hand.

Key Polymers

Polyesters

- ***Posted prices up***
- ***Capacity ample***
- ***Markets soft***

PRODUCTION/CAPACITY



HOW MADE

Mainly polyesterification of maleic and phthalic anhydrides with propylene glycol; cross-linked with styrene

MAJOR END USES

Construction 30%, marine 18%, castings 15%, transportation 8%

FOREIGN TRADE

Exports—1% of sales, imports—negligible

PRICES

General-purpose grade, 61 cents per lb

COMMERCIAL VALUE

$620 million for total production, 1981

Almost alone among U.S. thermoset resin manufacturers, unsaturated polyester producers predict a modest increase in their sales this year over last. Sales could reach 1.02 billion lb in 1981 compared with 950 million lb in 1980. On the other hand, renewed deterioration of auto and construction markets could reverse early growth trends, resulting in no increase over last year.

Troubles started earlier for polyesters and hit relatively harder than for any other thermoset. The downturn began in the marine and recreational vehicle market with the gasoline lines of April 1979. Though only 18% of polyesters go into boat building, the formulations used contain 65% resin as opposed to 35% resin in some building construction laminates. Thus what happens to marine sales has a dramatic effect on polyesters overall. Sales losses were most severe in August 1980, when the total market declined at an annual rate of 21%. A long, slow turnaround from that low point returned polyesters to positive growth, and by July 1981 sales were increasing 3% yearly.

This upturn in polyester fortunes is ascribed to confidence that economic policies of the Reagan Administration soon will arrest inflation and bring interest rates down. Though inflation may have abated, interest rates remain high, affecting purchases of items on which polyesters most depend—boats, cars, houses, and appliances.

The marine industry used 171 million lb of polyester in 1980, down 25% from 1979, according to figures from the Society of the Plastics Industry's committee on resin statistics as compiled by Ernst & Whinney. By midsummer, there were signs that about one third of this loss might be recovered this year.

The construction market took 287 million lb in 980, down 12% from the previous year. By June 1981, it seemed as though sales for construction might bounce back to 1979 levels. However, mortgage interest rates have averaged 17% this year, and housing starts continue down.

Transportation uses of polyester such as cars, trucks, and buses took 80 million lb in 1980, down 24% from the previous year. At the end of the first half of 1981, about half of this decline seemed likely to be restored. However, improved car sales resulted mainly from rebates offered by auto makers. Hence, this industry could remain static for polyesters if rebates cease with 1982 model introductions.

The 144 million lb of polyester used for castings such as furniture and imitation marble in 1980 was down 10% from 1979. This decline continued at a slightly accelerated pace in the first six months of 1981.

Throughout this period of declining sales, polyester producers have succeeded in raising prices. The average price of general-purpose polyester was 54 cents per lb in 1979 and 58 cents in 1980. It may be that prices will hold up at an average of 61 cents per lb in 1981. Deregulation of natural gas prices in 1982 may increase costs of raw material propylene and diethylene glycols and of maleic anhydride and styrene. Higher raw materials costs may push polyester prices as high as 68 cents in 1982.

Production of 100 lb of general-purpose polyester requires 43 lb of phthalic anhydride, derived mostly from petroleum-based *o*-xylene; 19 lb of maleic anhydride, about half of which comes from butane; and 38 lb of glycols, most of which comes from natural gas. In addition, the 100 lb of resin could be cross-linked with 70 lb of styrene, which itself contains 19 lb of mostly natural gas-derived ethylene. Thus about half the weight of polyester comes from natural gas.

Though the regulatory climate is more relaxed this year, polyester producers still expect some pressure from the Occupational Health & Safety Administration to lower present exposure limits on styrene in fabricating plant atmospheres. The present eight-hour, time-weighted limit is 100 ppm, and OSHA may press to lower that to 50 ppm. The industry is countering such a move by presenting data that no health advantage would result.

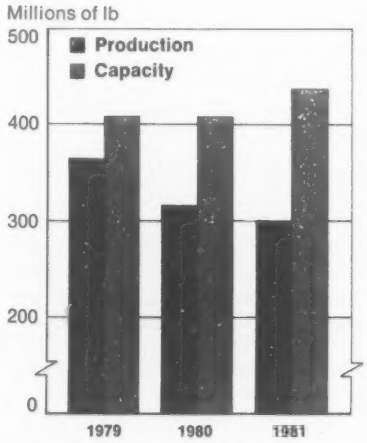
Boat builders would be especially hard hit by any lowering of these exposure limits, because such fabrication takes place in the open air. Larger, more efficient boat builders might survive by improving ventilation and work practices and by using styrene-suppressed resins containing waxes or other additives and less volatile monomers like acrylates and vinyltoluene.

Key Polymers

Epoxies

- ***Prices up a bit***
- ***Capacity increased***
- ***Markets flat***

PRODUCTION/CAPACITY



HOW MADE

Reaction of bisphenol A with epichlorohydrin followed by cross-linking with hardeners

MAJOR END USES

Coatings 48%, laminates and composites 22%, molding 9%, flooring 7%, adhesives 6%

FOREIGN TRADE

Exports—11%, imports—negligible

PRICES

Average $1.00 per lb

COMMERCIAL VALUE

About $300 million for total production, 1981

Performances of epoxy resin markets in 1981 demonstrate once again that the broad applications base and high-performance nature of these resins make them somewhat resistant to economic cycles. Still, domestic U.S. sales are likely to amount to 285 million lb in 1981, the same as in 1980.

Strengthening of the dollar will cut exports of epoxies back to 25 million to 30 million lb this year, compared with 35 million lb in 1980. Exports thus will remain at the traditional 11% of total sales of 310 million to 315 million lb for 1981.

Sales of epoxies revived in the second quarter of this year from low points relatively shallow compared to those of other, more mature thermosets. Sales for the 12 months ended in April 1981 were almost 8% lower than the year before. From that point, the running annual growth rate actually passed 3% in August. However, expected declines in automobile output and other industrial production, coupled with continuing troubles in the electronics industry, probably will drop the epoxy growth rate to zero by year's end.

Coatings sales of epoxies may remain the same in 1981 as in 1980—137 million lb. Can coatings sales are still strong, but automotive, appliance, and coil coatings probably will decrease. Because coatings account for almost half of all epoxy uses, stagnant sales here buffer epoxies from downturns elsewhere. Growth may return to 6% per year late in 1982.

Sales for laminates and composites may decline 5% to 60 million lb in 1981 from their 1980 level. Growth in corrosion-resistant pipe and tanks, especially for increased oil exploration, will be more than offset by losses in the electronics industry. After recovery, sales could grow 10% per year.

Commercial flooring will take 19 million lb of epoxies this year—the same as last year, with little or no growth seen in this end use over the long term. Adhesives sales also will remain flat at 18 million lb this year, though they may begin growing at 6% annually with recovery in the economy.

Weak markets in the electronics industry and in other industrial production will produce a drop in casting, molding, and tooling resins from 26 million lb in 1980 to 24 million lb in 1981. But these same uses are expected to produce 10% annual growth rates for these resins in the more distant future.

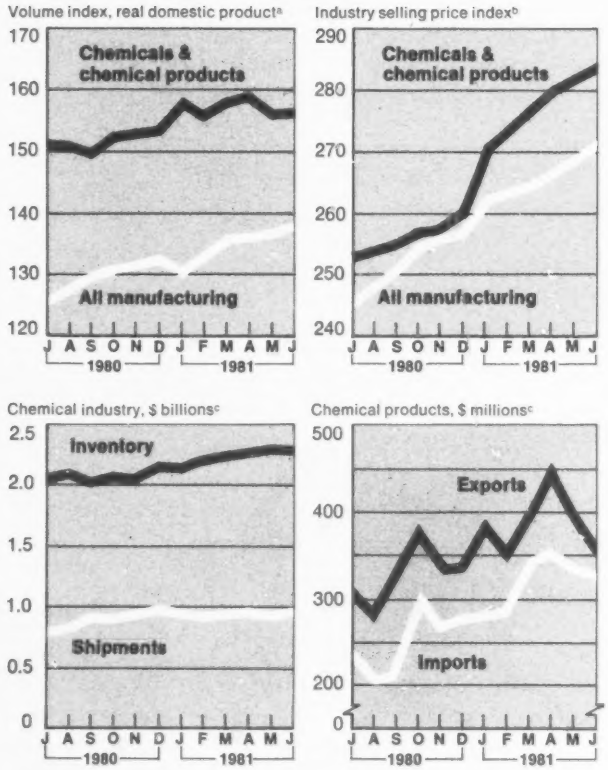
The more relaxed regulatory climate under the current Administration actually may prevent new epoxy sales increases from being created by regulations in the auto industry. Nevertheless, auto makers probably will continue to use more epoxy coatings for corrosion resistance. They also may continue to consider epoxy molded parts for under-the-hood applications to better compete against imported autos.

Nongovernment pressure also is responsible for a potential safety problem in organic diluents used with epoxies and has stimulated a continued search for diluents other than the present butyl and cresyl glycidyl ethers. Though new testing apparently exonerated butyl glycidyl ether from suspicions of carcinogenicity, unions reportedly are urging many large customers to insist on elimination of such low-molecular-weight, high-vapor-pressure diluents from formulations. One problem is that alternative compounds of higher molecular weight and lower vapor pressure might have to be used in larger amounts to give the same viscosity reductions. Such substitution would increase the cost of epoxies to users.

Another problem for epoxy may come in its export business, which is apparently much more important than indicated in data from primary resin makers. The Bureau of the Census lists 1980 exports of epoxies from all sources as 80 million lb, one fourth of total sales. Much of this market results from export of U.S. electronics and coatings technology. Users of these technologies in other countries often specify the same resin used successfully here. However, rising U.S. epoxy prices overseas resulting from a stronger dollar may make local production increasingly attractive to present epoxy-importing countries.

Prices also are up in the U.S. and tend to hold more strongly than for other thermosets. The average price is $1.00 per lb in 1981 compared with 94 cents in 1980. Epoxy producers are pricing to keep profit margins healthy, and the average price could be $1.06 per lb in 1982.

Canadian chemicals enjoy good first half



a Seasonally adjusted; 1971 = 100. b 1971 = 100. c Canadian dollars.
Source: Statistics Canada

Output is up for most chemicals

Production, thousands of metric tons	First half 1981	First half 1980	1980	% change
ORGANICS				
Ethylene	665	626	1184	6.3%
Propylene	328	288	590	13.9
Benzene	311	311	604	0
Toluene	219	241	538	−9.1
Xylene	209	180	478	16.1
PLASTICS				
Polyethylene, low density	230	212	439	8.5
Polyethylene, high density	113	96	202	17.7
INORGANICS				
Hydrochloric acid	92	87	177	5.6
Nitric acid	430	318	713	35.2
Phosphoric acid, 100% P_2O_5	406	414	808	−1.9
Sulfuric acid	2144	2219	4295	−3.3
Ammonia, anhydrous	1325	1265	2556	4.7
Ammonium phosphate	726	750	1466	−3.2
Chlorine	656	652	1303	0.6
Sodium hydroxide	733	730	1459	0.4

Source: Statistics Canada

The long-term future of the Canadian chemical industry may indeed turn out to be as bright as most analysts say that it will be. But for the immediate future, the outlook is far from exhilarating.

That's not necessarily the industry's fault. Although exports are becoming an increasingly important part of the chemical industry's business, its fortunes still are dictated in large part by Canada's overall economy. And right now, that economy is a mess. Inflation is running at an uncomfortably high rate of about 13%. Interest rates have soared, with the Canadian prime rate approaching 23% before declining a little recently.

Although the chemical industry remains one of the fastest growing in Canada, its major indicators seem to mirror what has been happening in the economy generally. For instance, when the Canadian economy nosedived in the first half of last year, the chemical industry's production index (the RDP, or real domestic product, index) dropped 4%. When the economy recovered in the second half, the industry's RDP index rose 4%.

All things considered the chemical industry enjoyed a good first half this year. Its RDP index rose 2% over the preceding half and 6% compared to first-half 1980.

Shipments of chemicals and chemical products hit $5.9 billion (Canadian) in the first half of 1981, up a healthy 12% over the first half of 1980. Much of that welcome growth, however, was the result of price increases. Now, growth in the chemical industry is flattening out, again reflecting the general Canadian economy.

While waiting for the government to unveil its budget next month, the mood of Canada's economic pulse takers is one of unrest and uncertainty, sprinkled with some concern that the country may be slipping into a recession. Best guesses are that the budget will be anti-inflationary rather than economy stimulating.

Whatever it turns out to be, the budget won't have much of an impact on economic performance for the rest of this year and may not have a bearing on business fortunes until 1983. Most Canadian economists expect a slowdown in economic growth for at least the next 12 months.

Meanwhile, Canadian GNP (gross national product) is expected to increase 3% in real terms this year. That may not sound bad, but most of that growth already has taken place in the first half of the year. The third and fourth quarters are expected to be virtually flat. If that's true, the chemical industry's business won't be booming for the remainder of the year, either.

As one expert explains it, economic recovery has ceased to be broad based. Although production has increased slightly at the industrial level over the past few months, demand has fallen off. The result has been an inventory buildup which industry leaders will try to correct over the remainder of the year.

There are few if any optimists about the outlook for the next six to eight months. Inflation still is high. Interest rates are high. The new budget is almost certain to contain tax increases. And the industry has substantial energy and feedstock cost increases to absorb. With all of this, it's hard to be optimistic.

Earl Anderson, New York

NOTE

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Chemical & Engineering NEWS

Phenol and vinyl acetate business remains poor
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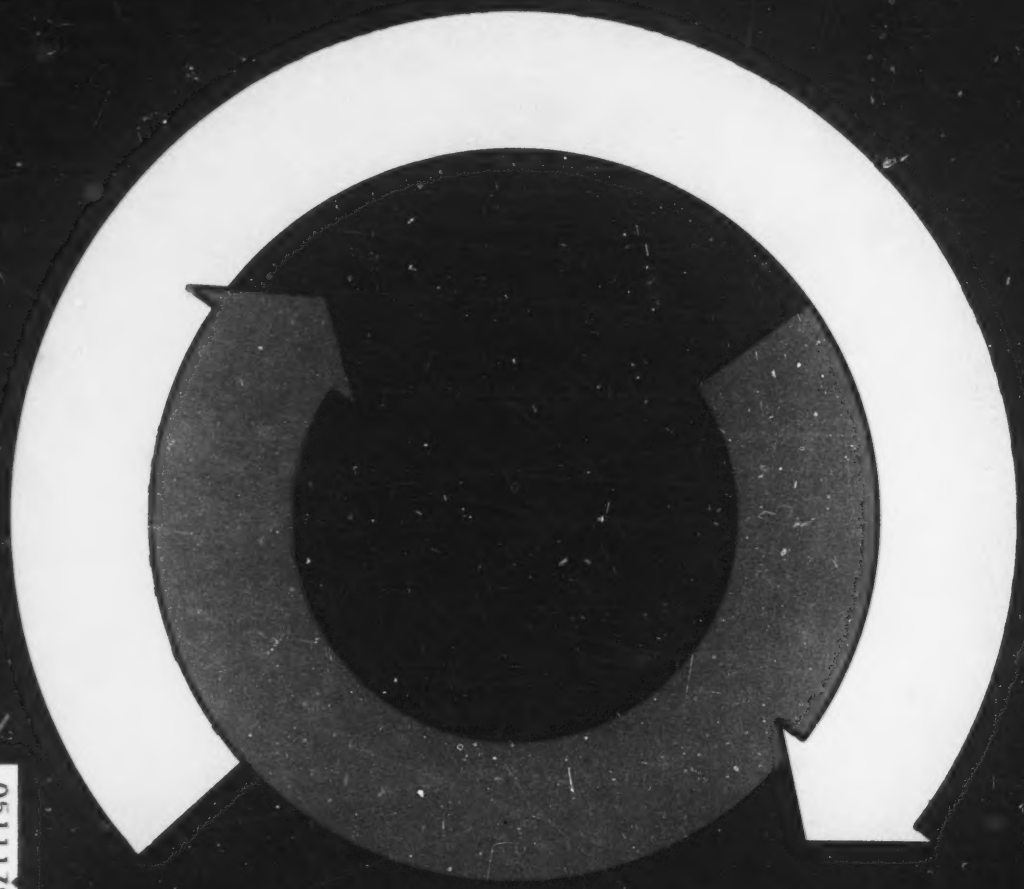

New directions for science in national security

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- ***EPA forced to release data*** *that it considers of questionable scientific validity under Freedom of Information Act.* ***Page 7***
- ***Warren M. Anderson*** *named chairman and chief executive at Union Carbide, succeeding retiring William S. Sneath.* ***Page 7***
- ***Merger of Du Pont and Conoco*** made official with approval of Conoco stockholders, filing of certificate of merger. ***Page 8***
- ***Eastman Kodak will use naphtha feedstock*** *for polyethylene complex in 10-year agreement with supplier Pennzoil.* ***Page 8***
- ***Goodrich will buy*** *Diamond Shamrock Plastics; purchase will bring company vinyl chloride and PVC plants in Texas.* ***Page 8***

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- ***Specially designed magnetic fields*** *greatly increase energy conversion from electron vibrational energy to laser light.* ***Page 31***

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Recovery still eludes phenol, vinyl acetate

Continued low housing starts and auto output keep demand flat for these adhesive and coating ingredients following slump in 1980

Producers of phenol and vinyl acetate still are waiting for a turnaround following last year's recession. Companies expect that 1981 will be another year of production below 1979, profits at marginal levels, and new expansion out of the question.

Hopes for a second-half 1981 recovery have been dashed for these derivatives of benzene and ethylene, used heavily in making various kinds of adhesives. In fact, there has been an apparent slowdown in demand during the third quarter.

A pickup in the fourth quarter doesn't seem likely for the major consumer products containing phenol and vinyl acetate. These markets face slumping demand or at best no growth. The durables that account for much end use of phenol and vinyl acetate—housing and automobiles—show no signs of a significant pickup until possibly well into 1982.

Even a small improvement in demand for housing and autos couldn't do much right away for phenol and vinyl acetate. Because of the long demand slump, producers of adhesives have more than enough inventory and, if anything, would like to reduce it. This means a delay in any recovery before a renewed push in the inventory pipeline gets back to these chemicals.

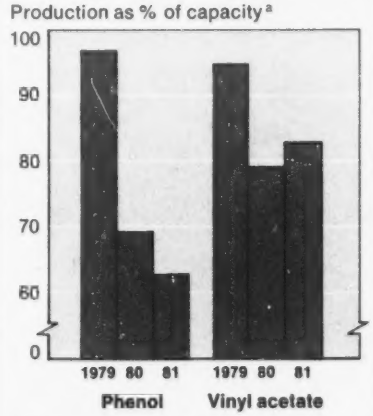
When demand improvement finally comes, possibly after 1982 with any strength, producers will have no problem in meeting demand for some time. Current excess plant capacity exceeds half of 1981 demand for phenol and a quarter of 1981 demand for vinyl acetate. Using up the current excess could take quite some time, especially for phenol, whose longer-term growth rate has been reduced by several industry analysts to 2 to 3% a year through 1985. Vinyl acetate, with a forecast growth rate at least double this pace, could run out of capacity in 1983 or perhaps 1984 if a demand recovery starts late in 1982.

Hence, it already could be time for initial planning on new investment in vinyl acetate capacity. Producers' investment strategy in the late 1970's was good enough to keep plant use in vinyl acetate reasonably high. By contrast, phenol represents one of the worst cases of investment planning among organic chemicals since 1975. Excess seems to have been the rule in the face of slowing demand.

Domestic demand growth will be more important than in the past for both of these products because of a decline in exports. Analysts fear that fresh antidumping duties on these products could come quickly in Europe and further depress exports. The conservative view is that, between such duties and rising costs of U.S. hydrocarbon feedstocks, exports can be expected only to decline.

Therefore in the U S. these chemicals need new uses and growth in current uses. At this time, the only major new use for either is in phenol as a raw material for making aniline. USS Chemicals part of U.S. Steel is building an aniline unit that potentially could require a bit over 200 million lb of phenol a year. This plant will begin operation in 1982. With startup, however, production could take some time to rise to capacity because of the slow state of markets.

Phenol's capacity use in 1981 is worse than in 1980



a First-quarter nameplate capacity.
Sources: Department of Commerce, International Trade Commission, industry and C&EN estimates

Besides the aniline outlet, new-use prospects for phenol are few. At this time, none of the many miscellaneous uses of phenol seem to offer much growth. Several of these smaller uses, each 2% of the total or less, are actually declining—for example, manufacture of the herbicide 2,4-D and of certain plasticizers.

Therefore, phenol will remain dependent on current large-scale uses to sustain even the low rates forecast by industry analysts. Phenolic resins, of which there are a myriad, have been commercial for more than 70 years and are hence a very mature product. If it weren't for their inexpensive adhesive properties, phenolic resins would be showing significant declines in demand because of replacement in many uses by other plastics, most notably polyolefins and nylons. As it is, this maturity of phenolic resins ties growth prospects of phenol in this large use to about that of the real-dollar gross national product.

A worse influence than gross national product is the close tie of phenolic resins to the housing industry. Phenolic resins are used in the great majority of plywood, much of which goes into housing and commercial buildings. About a third of phenol production goes to plywood and likely will hold at this level.

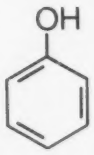
In contrast to phenol, vinyl acetate has no significant new uses coming in the next couple of years. Even so, vinyl acetate has much better prospects for long-term growth than does phenol. For example, paints and adhesives offer long-term growth rates of 4 to 5% a year for vinyl acetate. Copolymers with vinyl chloride or, particularly, ethylene look like comers with growth rates of about 10% a year for several years ahead. There is hope that vinyl acetate-ethylene polymers will find specialty uses of some size in "severe service" elastomers such as products used in high-temperature applications. These uses could spark vinyl acetate demand and bring production ahead of phenol's by the middle of the decade.

For details on the immediate outlook for phenol and vinyl acetate, see the following pages.

Bruce Greek, Houston

Key Chemicals

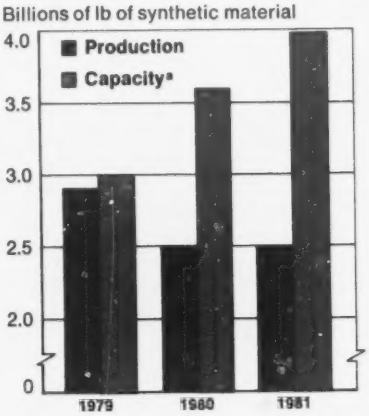
Phenol



- ***Output flat***
- ***Capacity may drop***
- ***Prices weak***

PRODUCTION/CAPACITY

Billions of lb of synthetic material



[a] As of first quarter.

HOW MADE

Mainly peroxidation of cumene, then cleavage to phenol and acetone

MAJOR DERIVATIVES (U.S.)

Resins (mostly with formaldehyde as comonomer) 40%, bisphenol A 20%

MAJOR END USES (U.S.)

Adhesives 60%, plastics 20%

FOREIGN TRADE

Exports—falling in 1981 to about 250 million lb, imports—negligible

PRICES

List prices, mostly near 36 cents per lb, with discounting

COMMERCIAL VALUE

$950 million for total production, 1981

Tied heavily to thermoset plastic outlets, which means to construction and auto markets, phenol is having a wretched year, as bad as recessionary 1980. If business doesn't get much worse than it has been, phenol production this year will about equal that of 1980, about 2.5 billion lb.

Some producers expect that 1981 production will exceed 1980's by 100 million lb or so. This amount, about 4%, would be hard to notice statistically. Since the 1980 production figure from the International Trade Commission is 2.46 billion lb, an additional 90 million lb at minimum would be required for production to exceed 2.5 billion lb when rounded off.

In addition to synthetic phenol, small quantities of "natural" phenol are produced in the U.S. each year. The amount has held at about 30 million lb in recent years, almost all recovered from caustic washes of effluent streams from catalytic cracking units in oil refineries. Very small quantities also may be recovered from coal tar. Natural phenol output may decline slowly in the next year or so as cracking operations fall with declining demand for gasoline. However, natural phenol supplies eventually would increase with large-scale use of coal to make synthetic fuels and gases.

In-place nameplate capacity to make synthetic phenol has reached 4 billion lb, including General Electric's new unit at Mount Vernon, Ind., where 400 million lb of nameplate capacity began startup in the fourth quarter of 1980. It also includes a unit of Shell Chemical at Deer Park, Tex., which was temporarily shut down following a fire in a cumene supply unit.

However, not all this capacity is operating. Some small units, with capacity of 300 million to 400 million lb a year, are shut down either temporarily or permanently, although permanent shutdown may be denied by the owners.

On a total nameplate basis, then, phenol production in 1981 represents capacity use of 63%, distressingly down from better days in 1979, when plants ran at their effective top capacity. However, if 10% of total capacity is subtracted for shutdowns, the operating rate rises to nearly 70%—still not very good.

Industry observers forecast that some additional phenol capacity might be shut down if demand doesn't pick up and if exports continue to fall under pressure of antidumping duties in Europe. If the shutdowns are small, phenol capacity in 1982 will remain more than adequate. If demand growth doesn't increase, this capacity will be sufficient for several more years.

The economics of restarting shutdown units indicate that capacity may become snug sooner than indicated by a simple comparison of future demand and current capacity figures. However, for now, economics clearly suggest that additional investment can't be justified.

It isn't hard to deduce that phenol profitability is quite low. Partly to blame is producers' discounting prices to keep plants running. In this respect phenol is no different from many other major organic chemicals.

One area of large discounts has been exports, which resulted in imposition of antidumping duties in the European Economic Community. For the U.S., this means that 1981 exports of phenol may decline 15 to 25% from 1980 exports of about 300 million lb, but most producers expect 1981 exports to total about 250 million lb.

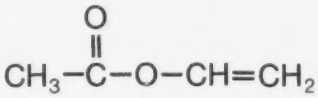
If exports do fall 50 million lb, this additional amount of phenol will have to be absorbed by U.S. markets, few of which have the strength. Resins, staggered by the decline in demand for adhesives used in building products such as plywood, paneling, insulation, and composites, aren't expected to recover until housing recovers. Bisphenol A seems a brighter spot, if auto production increases to use more product epoxy resins and possibly polycarbonates.

Other uses are small but might have good growth rates. The only major new use on the horizon is as a new starting material for aniline, but that won't become a factor until a year or more from now.

Even with the new aniline outlet, phenol has one of the more depressing prospects among organic chemicals. Although many industry analysts argued several years ago that investment was growing excessive in this aromatic, new capacity went up anyway. The results are all too clear.

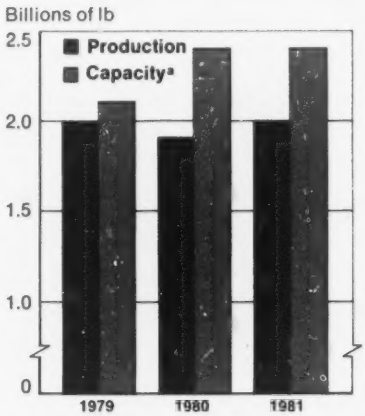
Key Chemicals

Vinyl Acetate



- ***Production steady***
- ***Capacity flat***
- ***Prices soft***

PRODUCTION/CAPACITY



a As of first quarter.

HOW MADE

Vapor-phase reaction of ethylene, acetic acid, and oxygen

MAJOR DERIVATIVES (U.S.)

Polymers 55%, polyvinyl alcohol 20%, copolymers 10%

MAJOR END USES (U.S.)

Adhesives 35%, paint 25%

FOREIGN TRADE

Exports—off slightly to about 600 million lb in 1981, imports—negligible

PRICES

List price 37.5 cents per lb, some discounting

COMMERCIAL VALUE

$725 million for total production, 1981

Heading into the fourth quarter, vinyl acetate is about to conclude its third straight flat year in terms of production. Output of this chemical, used mostly in polymers for adhesives and paints, will about reach 2 billion lb in 1981, the same as in 1979 and up slightly from 1980's output of 1.9 billion lb.

More detailed statistics from the International Trade Commission show 1979 output of 1.98 billion lb. Production declined to 1.92 billion lb in 1980 or about 3%, not too bad for a recession year. A 2 billion lb total for 1981 then would be a 4% gain.

This near-standstill in production isn't new for vinyl acetate. During the mid-1970's, production declined and required four years to exceed the previous record.

The 1980's might not take that long for new growth. Probably in 1982 production again will set a record—with a 6% gain to 2.3 billion lb. But how likely is this gain is a good question. Some industry observers forecast a lower range of 1.95 billion to 2.0 billion lb, because of unknowns in exports and a continued slump in housing starts. If exports sag further as a result of anti-dumping duties, then the U.S. market will have to increase to allow even a 2 billion lb year for vinyl acetate in 1982.

Producing this much will be easy for U.S. producers, whose nameplate capacity totals a bit more than 2.4 billion lb. The operating rate this year likely will be 83%, a relatively good rate among organic chemicals.

At this time, no capacity expansions are under way other than debottlenecking efforts, which might add 50 million to 100 million lb of capacity during the year. However, several producers have capacity expansion programs on the shelf, which could be implemented with ease as in Union Carbide's expansion early this year at Texas City, Tex.

Of the many organic chemicals now faced with excess capacity, vinyl acetate has better prospects for early capacity expansion than most. Industry sources expect 6% annual growth to follow the 1981 plateau. As a result, current capacity could be fully used on a practical basis within two years. This suggests that now would be the time to get started on major additional capacity, which takes at least two years to complete.

But the problem for vinyl acetate producers remains the same as in most other organic chemicals—profit levels don't justify additional investment at this time. Still, a better chance exists for incremental (smaller scale) expansion in vinyl acetate than for many other products because economically justifiable units for vinyl acetate are smaller. This is especially true if low-cost raw material acetic acid is readily available as a result of new technology.

As is the case for other large-volume chemicals whose identity is lost in subsequent processing, nearly half of vinyl acetate is consumed captively. This enables producers in effect to improve their profit margin downstream by avoiding outside purchase. However, unless the market for derivatives holds up, even captive users will have poor profit margins on vinyl acetate.

Currently, the major markets for vinyl acetate are sluggish. Adhesives reflect general industrial activity, which has slowed recently. The slowing appears to have translated back through the product chain, reducing vinyl acetate's growth in 1981 to a small amount, if any. A pickup will be delayed through inventory drawdowns.

Paints, the second largest use, suffer with the housing industry as do many adhesive uses. Maintenance painting seems to have held up pretty well, aiding trade sales of paint, but this type of sales has not met expectation during the second and third quarters. So paints, too, probably will record just minor growth as a use of vinyl acetate this year.

Copolymers with ethylene or vinyl chloride will have the best growth among significant uses of vinyl acetate. These uses are small but will grow relatively fast because of end-use demand for printing and other commercial papers and packaging materials.

Although such uses lift the long-run hopes for vinyl acetate, giving it one of the better outlooks among organic chemicals, these markets can't overcome the general economic sluggishness of the moment. Vinyl acetate resists downturns in the business cycle better than does phenol but must still idle another few quarters.

NOTE

ONLY THE FOLLOWING PAGES OF THIS

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Chemical & Engineering NEWS

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Biotechnology on campus

Business, academia in potential conflict of interest
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- ***Celanese will get out*** *of textured polyester yarn business by end of 1982.* ***Page 6***
- ***Du Pont and Seagram agree*** *to representation on each other's board.* ***Page 7***
- ***Congress criticizes Canada's clean air law*** *as weaker than that of U.S. at subcommittee hearings on acid rain.* ***Page 7***
- ***New ion injector*** *upgrades linear accelerator at Berkeley lab.* ***Page 8***
- ***Chemical industry executives' confidence*** *in business outlook is waning.* ***Page 8***
- ***Laboratory for research on submicron structures*** *opens at Cornell.* ***Page 8***

Business

- ***U.S. chemical plant capacity is down to 72%*** *in third quarter, bringing rash of cutbacks and temporary shutdowns.* ***Page 12***
- ***Lubrizol chairman Thomas W. Mastin wins*** *the Chemical Industry Medal of the Society of the Chemical Industry.* ***Page 14***
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International

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Government

- ***Federal regulatory agencies may increase*** *use of risk analysis as bill gains support in Congress.* ***Page 20***

Science

- ***Secondary ion mass spectroscopy*** *technique can detect and measure ions with high mass-to-charge ratios.* ***Page 24***
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- ***Soviet scientific official faced critics*** *of Soviet treatment of dissident scientists in unprecedented meeting at NIH.* ***Page 32***

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- ***Polymer batteries*** *more powerful and lighter than lead-acid cells may reach market in five to 10 years.* ***Page 34***
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News Feature

- ***Commercialization of biotechnology challenges academia*** *to deal with potential for conflicts of interest raised by increasing interactions with business.* ***Page 39***

FERTILIZERS FALTER, ADD TO ECONOMIC WOES

After giving many U.S. chemical companies a welcome counterthrust in the 1980 recession, much of the fertilizer business unhappily is adding to the economic pause currently restraining the industry's new expansion. Except in the nitrogen fertilizer group, the outlook has flip-flopped from buoyant to cautious.

A combination of negative factors promises fertilizers a more difficult time in the current fertilizer year started in July:

- U.S. demand is mildly up for ammonia and well up for urea in the nitrogen group but has gone soft in the leading type of potash and fallen badly in phosphates.
- Export demand, a big shot in the arm for the business in the past few years, also has weakened generally in recent months, dashing earlier hopes of a big contract expansion this summer.
- Many product prices have dropped, even though prices in the raw material chain have continued to rise, causing a profits squeeze.
- Continued plant expansion in the phosphates chain has only added to the slack.
- Fat U.S. crop yields this year after an excellent growing season warn of weak farm prices and possible slackening in fertilizer ordering.

The Fertilizer Institute's wrapup on the first two months of the new fertilizer year has some arresting figures. For the phosphates, production was down 31% in August from a year ago and down 18% for July and August combined. U.S. use also was down 5% in the two-month comparison, boosting inventories 28% by the end of August.

Within the phosphates group, important diammonium phosphate suffered a 24% production drop in July and August, while U.S. use fell 7% and inventories rose 31%. The DAP price has fallen more than 20% over the past year.

Even the precursor wet-process phosphoric acid, a strong market item in the past few years, fell 15% in output and 6% in use in July and August. On the Gulf Coast, industry sources say many phosphoric acid plants were taken down for maintenance this summer, recouping some advantage from the demand slowdown after high operating rates in the past two years.

In potash, the dominant standard muriate grade enjoyed a 15% production gain in July and August from a year ago. Unfortunately, use fell 5%, and inventories soared 100%. One potash company analyst estimates that U.S. mine capacity use in potash declined to 76% this summer from 86% last winter (see page 12).

Only the nitrogen group shows some steadiness. Ammonia production in July and August was even with a year ago; use went up 2% and inventories eased 8%. And durable urea (solid) moved up 10% in production from an already high level of a year ago. Urea use rose 32%.

Hopes were high for a spate of new export contracts this summer in downstream phosphate products, but the Fertilizer Institute says that exports of all phosphates in July and August decreased from last year excepting phosphoric acid. With phosphoric acid, there is a one-time influence this year from resumption of Hooker Chemical's large exports to the Soviet Union. This deal caused a 49% increase in overall phosphoric acid exports over the two months.

Big fertilizer producer International Minerals & Chemical warned last month that its earnings in the first fiscal half ending in December will decline from a year ago. Besides the effects of the stronger dollar and high interest rates, company chairman Richard A. Lenon blamed adverse conditions in phosphates combined with "repeated and unwarranted increases in the price of sulfur, a major ingredient in phosphate fertilizers."

IMC complaints on the sulfur price are a signal of new price resistance from big customers. Although sulfur and, until this year, phosphoric acid, have thrived with big price increases despite growing weakness in phosphates, they may not evade the change downstream much longer.

Although the Fertilizer Institute still voices "confidence in the fall and upcoming spring cropping seasons," Wall Street has decided otherwise. Fertilizer-heavy companies such as IMC, First Mississippi, and Williams Cos. are trading close to their lows for the past year, after magnifying the general stock market drop with respective declines of 53%, 57%, and 55% from their recent highs. □

Only nitrogen fertilizer output is higher than a year ago

Per cent	July-August 1981 change from 1980: Production	July-August 1981 change from 1980: U.S. use	August 1981 change from August 1980: Ending inventory
Nitrogen products	3%	9%	−6%
Ammonia	0	2	−8
Solutions	2	34	−16
Ammonium nitrate, solid	16	−6	30
Urea, solid	10	32	6
Phosphate rock	15	−13	31
Processed phosphates	−19	−5	28
Phosphoric acid (P_2O_5)	−15	−6	0
Concentrated superphosphate, all forms	1	−9	34
Diammonium phosphate	−24	−7	31
Potash products	−1	1	95
Standard muriate	15	−5	100
ALL PRODUCTS	−3%	5%	7%

Source: Tyson Belzer & Associates for the Fertilizer Institute; potash data from the Potash & Phosphate Institute

Celanese plans to quit textured polyester yarn

The long list of U.S. polyester fiber capacity shutdowns since the mid-1970's is continuing to grow. Celanese last week disclosed that it will halt production and sale of textured polyester yarn by the end of 1982.

The facilities involved are at Shelby, N.C., and Greenville, S.C., and are operated by Fiber Industries, which is 62.5% owned by Celanese. (The remainder is held by Imperial Chemical Industries.) The shutdown will leave Akzona as the only other major polyester fiber producer that texturizes its own yarn.

Celanese says that the withdrawal will be implemented in phases and is part of a plan to improve the long-term profitability of the polyester textile filament business. The company expects no significant impact on its 1981 income as a result of the closing. A positive impact is expected in 1982.

For the short term, the move by

Chemical capacity use slips to 72%

A new business slowdown shaved U.S. chemical plants' operating rate in the third quarter; many plants have been cut back or shut down

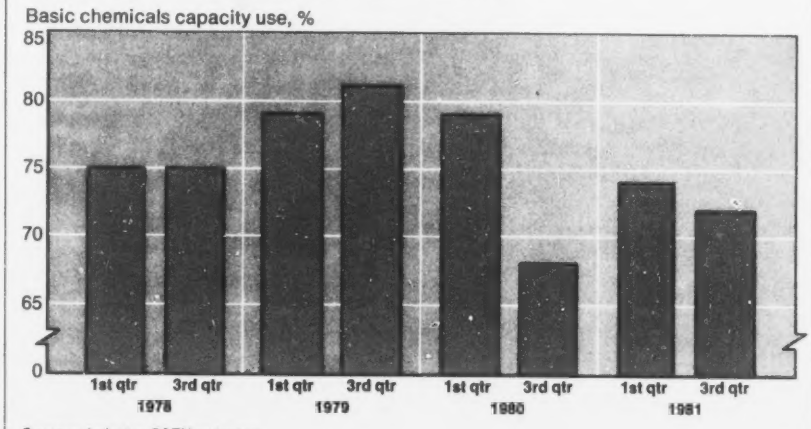
William F. Fallwell, C&EN Washington; Bruce F. Greek, C&EN Houston

A little backsliding. Not serious so far but not very welcome either.

That's the essential finding in C&EN's latest semiannual survey of plant use levels for the most important U.S. basic chemicals and polymers. For basic chemicals, average use of nameplate (official) plant capacity in the third quarter was 72%, down from 74% in the first quarter although still up from the recessionary pace of 68% in third-quarter 1980.

In polymers, the leading plastics throttled back to 76% capacity use in the third quarter from 80% in the first quarter. That's a significant drop but still leaves plastics well above their 55% level of the depths of the business slump a year ago.

Recovery in capacity use has stalled



Sources: Industry, C&EN estimates

Fibers, as they have all along in the 1980's, lead the pack in capacity use with a healthy 86% average in the third quarter. This is still up from 85% in the first quarter but masks a considerably weakened business posture. Fibers paid a price for high capacity use this summer in a troubling inventory buildup. Later statistics undoubtedly will show a pullback in plant use similar to that in other chemical products.

The few percentage points lost in overall capacity use levels in the third quarter may not seem alarming on the surface. But it doesn't take much of a change in gross averages to send the industry from well-off to so-so. Nameplate use of 85% or higher is generally prosperous, whereas use levels of 70% and lower can wipe out profits.

The industry's disappointment in third-quarter performance is all the

Plant use stays up in fibers but falls in plastics

	Third-quarter 1981			First-quarter 1981			Third-quarter 1980		
	Capacity	Capacity use		Capacity	Capacity use		Capacity	Capacity use	
Billions of lb per year	(nameplate)	Nameplate	Effective	(nameplate)	Nameplate	Effective	(nameplate)	Nameplate	Effective
Plastics									
Polyethylene, low-density	9.0	84%	89%	8.9	93%	99%	8.9	63%	67%
Polyvinyl chloride	8.1	75	87	7.8	77	89	7.8	49	57
Polyethylene, high density	6.0	83	87	6.0	80	84	5.8	62	65
Polypropylene	5.3	77	86	5.1	82	91	5.4	52	58
Polystyrene[a]	5.7	60	71	5.7	68	80	5.4	48	56
AVERAGE		**76%**	**84%**		**80%**	**89%**		**55%**	**61%**
Synthetic fibers									
Filament yarn									
Polyester	1.8	93	99	1.9	82	87	2.1	64	68
Nylon	1.9	84	89	2.0	88	94	2.1	64	68
Olefin	0.94	69	73	0.90	69	73	0.93	67	71
Staple									
Polyester	2.7	97	103	2.8	93	99	2.7	92	98
Nylon	0.97	94	100	0.99	86	91	1.0	77	82
Acrylic	0.83	79	84	0.83	93	99	0.85	83	88
AVERAGE		**86%**	**91%**		**85%**	**90%**		**75%**	**79%**
OVERALL AVERAGE		**81%**	**88%**		**83%**	**90%**		**66%**	**71%**

a Between 5% and 10% of this capacity is shut down. **Sources:** Industry sources, Society of the Plastics Industry, Textile Economics Bureau, C&EN estimates

Chemical plant use has dropped a notch from early 1981

Billions of lb per year unless otherwise noted[a]	Third-quarter 1981			First-quarter 1981			Third-quarter 1980		
	Capacity (nameplate)	Capacity use Nameplate	Capacity use Effective	Capacity (nameplate)	Capacity use Nameplate	Capacity use Effective	Capacity (nameplate)	Capacity use Nameplate	Capacity use Effective
Petrochemicals—olefins and aromatics[b]									
Ethylene	41.0	65%	72%	40.0	68%	76%	40.0	63%	70%
Propylene (chemical)	23.5	59	66	23.5	58	64	23.7	48	53
Butadiene[c]	4.6	67	74	4.6	61	68	4.0	65	72
Benzene (bg)	2.7	67	74	2.5	68	76	2.4	64	70
***p*-Xylene**	5.6	64	67	5.6	75	79	5.6	68	72
Petrochemicals—C_1 derivatives									
Ammonia (mt)[d]	24.0	80	84	24.0	83	88	24.0	75	79
Urea (mt)[d]	8.0	90	100	8.0	88	98	8.0	91	101
Methanol (bg)	1.4	83	92	1.4	90	100	1.4	80	89
Formaldehyde (37% solution)	8.9	65	68	8.9	66	69	8.6	59	62
Chlor-alkalies									
Chlorine (mt)	14.8	78	82	14.7	73	77	14.6	69	73
Caustic soda (mt)	15.5	75	79	15.6	73	77	15.3	68	72
Soda ash (mt)	10.0	83	87	10.0	82	86	9.7	79	83
Acids									
Sulfuric (mt)	58.5	74	78	58.3	74	78	58.0	76	80
Phosphoric (P_2O_5, mt)[e]	11.5	91	96	11.7	94	99	11.7	87	92
Industrial gases									
Oxygen / **Nitrogen** (total, liquid, ttd)	36.0	66	83	34.8	63	80	33.6	69	85
Carbon dioxide (ttd)	16.4	71	80	15.6	69	78	15.6	68	77
Mineral-based inorganics									
Sulfur (total, mlt)	16.0	68	—	15.4	76	—	14.5	72	—
Potash (mt)	2.9	76	—	2.9	86	—	2.9	86	—
Phosphorus (mt)	0.55	78	82	0.55	78	82	0.55	70	74
Plastics monomers									
Styrene	8.9	74	87	8.9	82	96	8.9	55	58
Vinyl chloride	9.7	70	77	9.2	70	77	8.2	63	70
Toluene diisocyanate	0.73	81	90	0.73	87	96	0.73	67	75
Fiber monomers									
DMT-PTA[f]	7.3	71	83	7.3	71	83	7.3	59	69
Ethylene oxide	6.8	72	80	6.8	65	73	6.6	70	78
Cyclohexane	3.4	59	62	3.4	62	65	3.4	52	55
Adhesives and coatings monomers									
Phenol	4.0	67	74	3.6	69	77	3.7	65	72
Vinyl acetate	2.4	79	83	2.5	78	82	2.5	68	72
Pigments									
Carbon black	3.4	82	91	3.7	76	84	3.7	61	68
Titanium dioxide (mt)	1.0	82	96	1.0	77	91	1.0	66	78
Solvents									
Acetone	3.6	58	65	3.5	58	65	3.3	61	68
Ethanol (mg)	300	56	59	270	65	69	270	69	73
Methylene chloride	0.83	64	71	0.83	75	83	0.80	63	70
AVERAGE		**72%**	**79%**		**74%**	**81%**		**68%**	**74%**

a bg = billions of gal, mt = millions of tons, tt = thousands of tons, ttd = thousands of tons per day, mlt = millions of long tons, mg = millions of gal. b About 20% of ethylene and lesser amounts of other capacity currently is shut down because of weak markets. c Includes extraction capacity of steam-cracking olefins plants, dehydrogenation and extraction capacity of dehydrogenation plants, and other butadiene recovery capacity. d Some capacity probably still shut down, less than 15% for ammonia and less than 5% for urea. e Includes both wet-process and furnace capacity. f Dimethyl terephthalate plus purified terephthalic acid, not including acid converted to DMT. **Sources:** Industry and government sources, C&EN estimates

more clear from its changed position in the capacity use range. The capacity use pickup from mid-1980 to first-quarter 1981 (C&EN, May 25, page 13) looked right on target for the general forecast of recovery this year. Another few percentage points gain could have led chemicals into a very decent second half. Indeed, such a course was widely expected.

Instead, by late spring it was clear that something had gone wrong. First fibers and then many other product groups showed a flattening trend in markets as plant capacity slowly expanded. So just as plant use approached the comfortable range, business underpinnings began to slip. And the prospect of financial strengthening in the second half receded into 1982.

Management reaction to the changed business climate has been swift. Unlike the reaction to similar periods in the past, decisions have come fast on adjusting plant operations. The unusual result this time is a rash of production cutbacks and temporary shutdowns. In some cases, as in fertilizer-oriented products like phosphoric acid, companies have

C&EN's capacity use indicator—the ground rules

Capacity use at chemical plants is difficult to measure and requires certain assumptions. These bring some order to the maze of variables affecting this critical indicator of the industry's health.

With the help of industry and government sources, C&EN measures capacity use as a percentage of both nameplate and effective maximums. Nameplate capacity is the official design capacity of plants. Effective capacity is the practical maximum after reductions for unplanned maintenance, corrosion problems, changes in product mix, and other influences. Although engineering companies and industry statistics groups try to make nameplate capacity data as "real" as possible, practical problems almost always reduce effective maximums to 85 to 95% of the official totals. For short periods, plants can run over 100% of effective top capacity, but such a rate won't last more than a few months.

Capacity use is given over as much of a calendar quarter as production data permit, with no seasonal adjustment. The figures are intended for plants actually running. At present, some products such as ethylene, polystyrene, and ammonia have plants temporarily shut down due to weak markets. These plants are still included in capacity totals. The totals exclude new plants just starting up and old plants out of operation for long periods because of accidents. As much as possible, capacity figures stay current with expansions.

Capacity data don't take into account other temporary fluctuations for fuel and electric power interruptions, equipment failure, and feedstock scarcity or substitution. The feedstock variables have been important in the past few years in basic olefins production, further reducing maximum output for several coproducts such as propylene, butadiene, and benzene.

Products in C&EN's capacity use survey are the same as those in the Key Chemical and Key Polymers series. These are the core products of the industry, the building blocks leading to downstream production of thousands of more specialized products.

taken plants down for thorough maintenance after long periods of high operation. But in many other products like ethylene and coproduct olefins and aromatics, companies have been forced to take plants out of operation by simple economics. For example, from 15 to 20% of ethylene capacity is now idle, including some very large new plants that have no customers.

The new math of plant operation rests on one main economic development of the past 10 years—the steep rise in raw materials costs' percentage of total production costs. Since raw materials are part of a plant's variable costs, in contrast to fixed costs such as the capital investment in the plant, managements today are much less likely to try to keep a plant running if business turns sour. It's considered better to stop the variable cost drain by shutting the plant down. In the past, a relatively higher load of fixed costs in plants influenced managements to keep plants running even in poor years.

Another factor in companies' quick action in plant shutdowns is a tougher marketplace this year. Burdened with profit problems of their own, chemical customers have hit chemical producers hard in recent months on pricing. Discounting already was well established as the year began but now has become epidemic. Unofficial price cuts have gone up to 25% in thermoplastics and basic petrochemicals. Although Gulf Coast sources say not much product is going through at the lowest prices, the new range is staggering—for example, down to 22 cents a lb from a list price of 28 cents in ethylene.

A serious new depressant in chemical pricing arose this summer in the formerly robust export market. Government statistics caught up with the export turnaround in August (C&EN, Oct. 5, page 10), but chemical marketers have felt the export drag all year. From mid-1978 through 1980, chemical exports were an important quiet booster for prices, production, and profits. This advantage has completely reversed. Now export sales calibrate the low end of the price range, and U.S. producers are accused of dumping some products.

By individual product line, chemicals show considerable variation between the most highly discounted, weakest groups and a few still performing well. Only one product among basic chemicals, urea, is still going all out, with 100% use of effective top capacity. Urea's product group, the derivatives of methane from natural gas, showed about the best prospects of any as 1981 began. Much of this promise still holds, even though their important fertilizer markets have slipped in recent months.

However, for these chemicals' cousins in olefins and aromatics, the picture is much darker. Plant use for the entire group is low, easing to a very poor 65% for kingpin ethylene in the third quarter from 68% in the first quarter. For ethylene, the 1980 recession hasn't yet ended. A year ago, plant use of 63% wasn't much worse than it is now.

Within the capacity use average of 65%, ethylene plant use varies considerably. Since up to 20% of capacity is idle, plants in operation average more than 80% capacity use.

Some ethylene coproducts such as propylene have even lower capacity use rates. This results from propylene's dual source structure in olefins plants and oil refineries, both of which are operating at low levels, Also, substitution of lighter feedstocks for naphtha and gas oil in olefins plants has lowered the output of coproducts.

The organic intermediates directly downstream from basic olefins and aromatics also are generally in financial trouble at the moment. This is apparent from nameplate use levels of, for example, 74% in styrene, 70% in vinyl chloride, 71% in dimethyl terephthalate/terephthalic acid, 72% in ethylene oxide, and 67% in phenol.

There isn't much wrong with any of these chemicals that couldn't be greatly aided with about five to 10 percentage points rise in plant use. One good market year could do it for many products. However, surrounding conditions in the U.S. and other economies rule this out for 1981. Capacity use this year, as in 1976 and 1977, will languish generally between 70 and 75%. □

Lubrizol's Mastin wins SCI medal

When Thomas W. Mastin, chairman of Lubrizol, accepts the Chemical Industry Medal of the Society of the Chemical Industry in New York City this week, he will talk about Homo sapiens' ability to survive.

The topic is dear to Mastin, a keen observer of nature and people's place in it, through his interests in biology, ornithology, and, of course, chemistry.

Mastin began his career at a much smaller Lubrizol in 1942 as a research chemist. When he started at the Cleveland-based producer of auto-

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Chemical & Engineering NEWS

Study names most highly cited scientists Page 30

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For chemists, is a Ph.D. really necessary?

Employment Outlook 1982

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News of the Week

- ***President's proposals*** *to increase emphasis on use and efficiency of nuclear energy in the U.S. find critics in Congress, antinuclear groups, and industry.* ***Page 8***
- ***Canada steps up lobbying*** *for U.S. cooperation in controlling acid rain, issues fisheries subcommittee report.* ***Page 9***
- ***Enoxy,*** *international chemical and coal company, is about to be formed by Italy's ENI and Occidental Petroleum.* ***Page 9***

Business

- ***American Hoechst's program*** *to increase sales and improve profits succeeds in pulling the company out of a $10 million loss sustained in 1980.* ***Page 13***

International

- ***Western European chemicals output*** *is rising slightly as are sales, but profits aren't necessarily keeping pace.* ***Page 15***
- ***Eastern Canada's petrochemical makers*** *can play a big part in the nation's industry if problem of upgrading heavier crudes can be solved economically.* ***Page 16***

Government

- ***Federal patent policy*** *under which contractors could retain title to inventions developed with government funds has support of Administration and Congress.* ***Page 24***

Science

- ***Most-cited scientist list,*** *published by Institute for Scientific Information, shows chemists well represented.* ***Page 30***
- ***Stellar region near the North Star*** *found by astronomers to be almost devoid of visible galaxies.* ***Page 33***

Technology

- ***Gas industry leery of rapid deregulation;*** *long-term benefits welcome but not at cost of short-term disorder.* ***Page 34***
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1982 Employment Outlook

Employment opportunities remain solid *and salaries are up, according to C&EN's annual survey of job prospects for chemical professionals.* ***Page 41***

Books

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- ***Official reports*** *of the board of directors meeting in New York City.* ***Page 83***

European chemicals output shows modest rise

Performance of Western Europe's chemical industry in 1981 is following the pattern that business leaders and forecasters were predicting last year. Overall, output showed modest growth between January and June. But many companies registered losses during the first half of the business year against an increase in sales.

The seasonally adjusted chemical production index for France in January, at 158 (1970 = 100), was back to the level of January 1979. It slipped a further eight points in February before moving up again to 164 in May, the most recent month for which data are available.

Assuming the rise continued in June, bringing the reading to about 165, the first six months of this year would show an increase of 4%. Though modest, this would be more welcome than the almost 10% fall that occurred between January and June a year ago. On the other hand, a projected value of 165 for the French June production index may be overgenerous. June readings in 1979 and 1980 were below those of May in both years.

West Germany's chemical production index rating in June, at 147 (1970 = 100), was 6.7% up on January's. This bettered the 2.8% rise in last year's first six months. However, the June reading was the same as May's, and only slightly ahead of the year-earlier level. And July's reading of 132 was well under the high so far this year of 158 in February and March.

Admittedly, July and August are slack business months throughout Europe. So a midyear dip is predictable on the experience of past years.

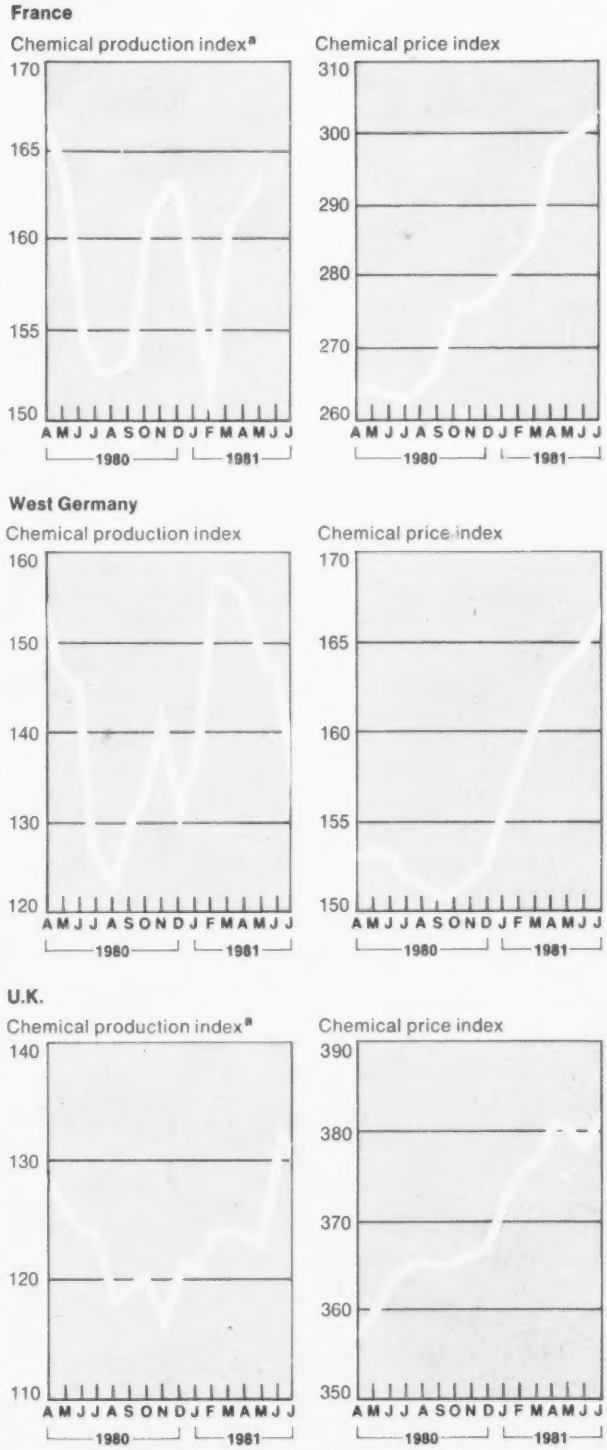
The 10.6% rise in the U.K.'s chemical output index value between January and June this year represents a decided turnaround from the 12.3% fall over the like 1980 period. At the same time, the monthly average of 125 (1970 = 100) was nearly 7% below last year's January-to-June average. And production in July slipped a couple of points from June's 133 reading to 131.

Chemical wholesale prices continued their upward trend. France registered the largest increase—7%—during this year's first half, matching exactly the rise in the like 1980 time span. West Germany was a close second with a rise of almost 6%, an improvement on the 2.5% advance the year before. For the U.K., the improvement was a meager 1.5%, in contrast to the nearly 6% between January and June 1980.

Underlying confidence in the future outlook for the chemical industry on the part of West Germany might be assumed from the fact that the 549,000 employment level in July was up 1000 from January. For the U.K., however, the steady downward drift in the number of workers in the industry continued. Last June, the figure totaled 393,000, in contrast to January's 407,000, and the 432,000 in January 1980.

According to the most recent survey published last month by Manpower Ltd., "Job prospects in chemical manufacturing [in the U.K.] could be stabilizing, although no early recovery in employment levels should be looked for." The survey shows that 10% of the firms contacted plan to take on staff members in the final quarter of this year, compared to the 7% who made a similar prediction a year ago.

Dermot O'Sullivan, London



a Seasonally adjusted **Note:** Base year for all indexes is 1970 = 100.

Eastern Canada sees big role in nation's petrochemical plans

Most of the well-publicized expansion in the Canadian petrochemical industry is taking place in the gas-rich western provinces. But that doesn't mean that the East is about to roll over and play dead.

Chemical companies in that neck of the woods, particularly in Quebec, think that they have a definite role to play in Canada's petrochemical future.

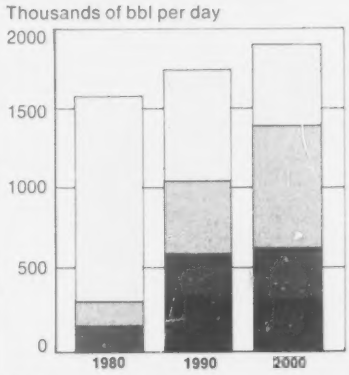
In the West, expansions will be based on natural gas and ethane. In the East, the industry will continue to be based primarily on crude oil. But for eastern producers, their ace in the hole is the fact that the complete petrochemical spectrum can't be satisfied from ethane alone.

The oil-based olefins producer in eastern Canada is not only close to the country's major markets, but can produce important by-products that cannot be produced from ethane and only to a limited extent from propane. Propylene, butylenes, butadiene, and the major aromatics are all primarily the forte of the oil-based producer.

Admittedly, the feedstock picture is more difficult for eastern Canadian producers than it is for their western counterparts. One major obstacle could be Canada's still-controversial National Energy Program (NEP), which stipulates that the petrochemical industry should use no more crude oil for feedstock than it does now. That provision, however, isn't set in concrete.

Meanwhile, several feedstock situations could develop that could work to the advantage of eastern petrochemical producers. Not the least of them is the way that eastern Canadian refiners solve their upgrading problem to handle heavier crudes and reduce the growing surplus of heavy fuels.

Canada's light crude production will decline



Source: Gulf Canada Products Co.

Barry P. Welford, vice president of Petromont Inc., outlined some potentially advantageous possibilities at the Second World Congress of Chemical Engineering in Montreal. Petromont has a big stake in these developments.

It has 670,000 metric tons of petrochemical capacity at two plants in the Montreal area, including ethylene, propylene, and mixed C-4's. The company is a limited partnership formed by Gulf Canada Ltd., Union Carbide Canada, and Ethylec Inc., which is a wholly owned subsidiary of Société générale de financement du Quebec (a crown corporation of the Quebec government).

One possibility, says Welford, is to make olefins from LPG (liquefied petroleum gas). This is receiving increasing attention, particularly since NEP was introduced.

Historically, propane has not been a major feedstock in eastern Canada. Infrastructure exists to move propane as far east as Sarnia, Ont., but the system does not extend to Montreal. As a result of this problem, the cost of propane in the Montreal area has been too high.

The cost may remain high. Both propane and crude oil are getting more expensive compared to natural gas. And to justify converting from naphtha to propane, the price of propane would have to be between 74 and 84% of naphtha's price. LPG terminals also would have to be built in the Montreal area.

Because ethylene prices in North America tend to be proportionately lower compared to other coproducts, Welford thinks that even larger price differentials may be necessary. Nevertheless, he points out, Canada exports about 60,000 barrels per day of propane and about 50,000 bbl per day of butane. That means that there is some room for further upgrading, which is what Canada wants to do.

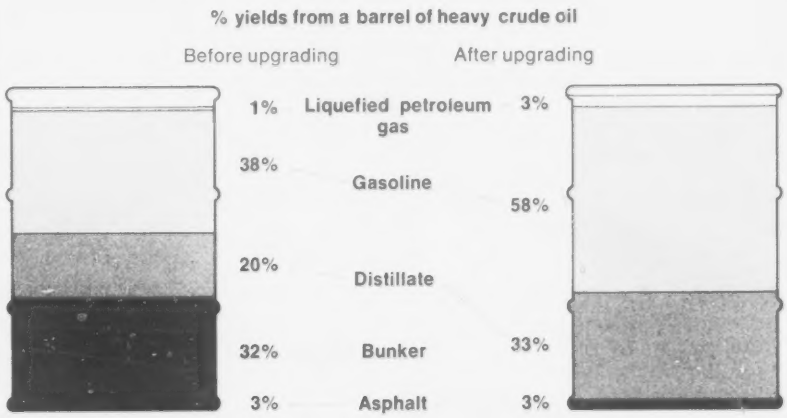
The oil and gas exploration activity that is taking place along the Canadian east coast also may affect petrochemicals in the Montreal area, according to Welford. Hibernia and Sable Island have significant hydrocarbon deposits and will be developed extensively in the 1980's. Areas farther north also look very promising, he adds.

Already there is talk of developing a petrochemical industry in the Atlantic provinces based on these resources but Welford says that the Montreal area could reap some of the benefits as well.

The present gas pipeline, which is being extended to connect the Maritime Provinces with Montreal, could bring natural gas feedstock to Montreal if it were made reversible. Also, says Welford, if oil comes into Montreal from offshore, then the line between Sarnia and Montreal could be reversed to allow oil feedstock to flow into the Sarnia area.

Another possibility for olefins producers near Montreal is to move toward heavier feedstocks. Welford

Upgrading removes residual fuel



Source: Gulf Canada Products Co.

cites the Idemitsu technology in Japan as well as Union Carbide's advanced cracking reactor (ACR) and Gulf's thermal regenerative cracker (TRC) as indicators of feedstock trends.

Welford also says that with the technology that is becoming available, it may be possible for petrochemical companies located near Montreal to increase their feedstock volumes and help solve a steadily worsening problem at the same time. That problem is an increasing excess of heavy fuel oils.

Several new technologies are being developed to improve olefins yields from distillate or gas oil. And the huge heavy oil upgrader now being proposed for Montreal would increase substantially the amount of distillate available in the area. There is a trend toward lower gasoline and home heating oil consumption, which means more of the distillate could be earmarked for petrochemical feedstock.

But the Montreal upgrader will be an expensive and complex project. In part, it will be complex because it involves six companies joining together in a single refinery project. Originally, there were eight. Imperial Oil withdrew from the consortium and Petrofina's share now is represented by Petro-Canada, which acquired Petrofina.

Other company members are BP Canada, Gulf Canada Products Co., Shell Canada, and Texaco Canada. The group also includes Soquip, the petroleum agency of the Quebec government.

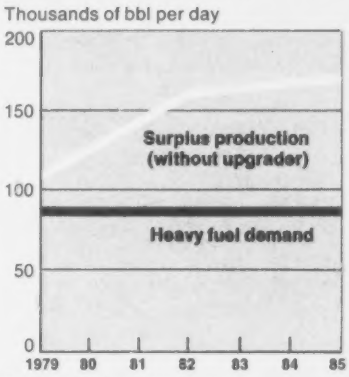
The Montreal upgrader is an outgrowth of a catch-22 situation in which eastern Canada finds itself. It already faces an oversupply of heavy fuel oil and this excess is forecast to get worse.

Canadian crude oil production is certain to decline during the 1980's and this will mean that Canada will have to import even more crude oil than it does at the present time. However, according to projections, the availability of light crudes in the international marketplace is decreasing and Canada will have to settle for more sulfur-containing heavy crude oil.

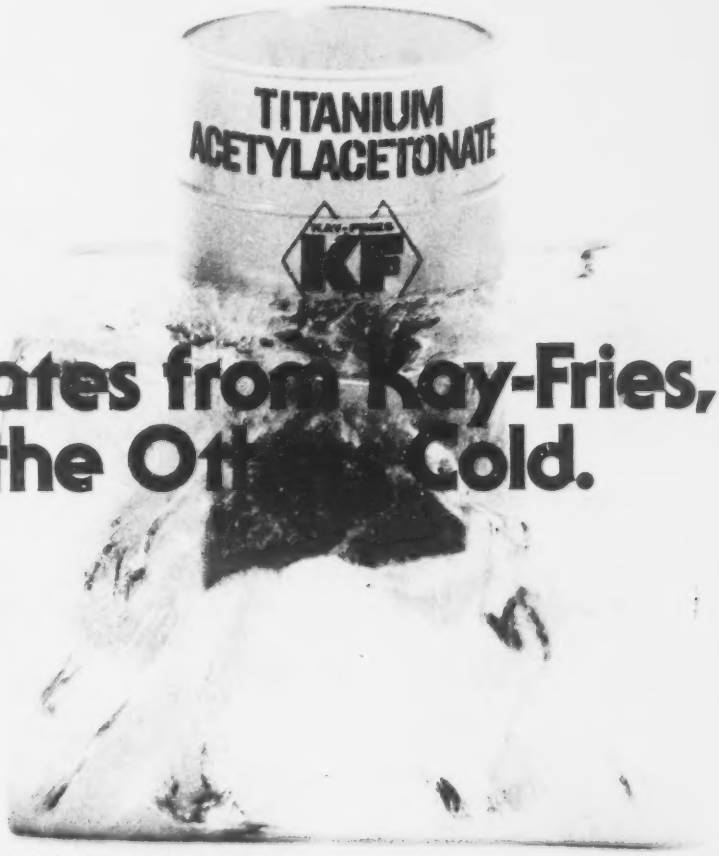
Without upgrading, however, heavier crude means that more crude will be required to meet light oil demands. As a result, an even larger oversupply of heavy fuel oil will develop.

To make matters worse, natural gas from western Canada may become more of a factor in Quebec and the Maritime Provinces if the natural gas pipeline is extended eastward as

Quebec heavy fuel surplus will rise without upgrader



Source: Gulf Canada Products Co.



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proposed in NEP. This will further cut demand for heavy fuel oil and No. 2 fuel oil, which already is in oversupply. And as this natural gas (and electricity) displaces fuel oil, refiners will have to face the prospects of upgrading home heating oil to diesel quality.

The proposed way out of eastern Canada's dilemma is a giant oil upgrader in Montreal. Without it, Canada almost certainly will have to import more light crude (if it can get it) at higher prices. And it runs the risk of having to import products such as gasoline and diesel fuel if supplies turn tight.

Upgrading converts the bottom of the barrel—bunker and asphalt—into lighter products such as gasoline and middle distillates, including diesel and jet fuels for which there will be increased demand. Gasoline yield is increased from 38% of the barrel to 58%. Distillates rise from 20% to 33%. Bunker yield is eliminated.

Each refinery in the Montreal area looked at schemes for handling their excess heavy fuel oil production. But it became apparent that they could gain some economy of scale if they formed a joint venture to build a much larger upgrader designed to meet the needs of all eastern Montreal refiners.

The project will cost a hefty $1.5 billion (Canadian 1981 dollars). Although the site is still under study, construction probably will begin in late 1982, with startup expected in late 1985 or early 1986.

According to N. R. Gravino, director of Gulf Oil Products Co., the project entered its second stage in July. The second phase is expected to last nine months and cost about $7 million.

Gravino will head a full-time project team to develop a design, construction schedule, and cost estimate. The final decision to build will be made after the team's work is completed.

It won't be easy. Joint refinery ventures are very rare. One company may build or expand its refinery to process another company's product. But never in Canada, says Gravino, have two or more companies joined to build a common secondary processing unit.

Because each refiner in the venture operates differently, the upgrader will have to handle several different feedstocks. This could create problems. And traditional refinery secrecy will have to be pierced to operate the upgrader.

The project involves many risks: uncertainty about volume of residual oil and refined products demand; the timing of additional supplies from tar sands plants, from offshore east coast, and from Beaufort Sea; and the degree and rate of natural gas and electricity penetration in eastern Canada.

Some are afraid that the upgrader could reduce throughput of existing refineries in eastern Montreal and threaten their economies because of the lower volumes processed. Tax and regulatory changes could destroy the project's economics. And there is always inflation and the increased cost of money.

But Gravino says that the consequences are too high for the upgrader not to happen. And if it does happen, more feedstock will become available for eastern Canada's petrochemical producers. □

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Chemists a fourth of most-cited scientists

Institute for Scientific Information identifies 1000 physical and life scientists whose publications are most often cited by other workers

Stephen C. Stinson
C&EN, New York

A list of the world's 1000 most highly cited scientists has been published by Institute for Scientific Information, Philadelphia (*Current Contents*, Oct. 12, page 5). These are the 1000 physical and life scientists and mathematicians whose work published between 1965 and 1978 was most frequently cited by other workers in their own papers published in the same period. Thus they are among the scientists whose recent work may have had the highest impact on contemporary science.

"Studies such as this one are of interest to awards committees who may be searching for worthy candidates to honor," says an ISI spokesman. "Colleges and universities can identify prominent alumni or present staff members who have achieved high impact."

Appearance of the present list also may add fuel to a continuing controversy about the significance of citation studies. In an essay that accompanies the list, ISI president Eugene Garfield cautions against overinterpreting numbers of citations or the presence or absence of one scientist or field.

The list contains 272 chemists, counting 84 biochemists, two chemical physicists, and 67 molecular biologists, but excluding 59 pharmacologists. There are no mathematicians, but this may be because mathematics is too small a field, or because mathematics journals average fewer footnotes than those in other fields.

Forty-one of all scientists listed have won Nobel Prizes. ISI identified 23 women according to feminine-sounding given names. The oldest scientist is microbiologist Fritz A. Lipmann of Rockefeller University, New York City, 82 years old, whose work cited by other scientists in the ISI study was done after he was 66. The youngest is 33-year-old physicist John S. Whitaker of Massachusetts Institute of Technology.

Among branches of chemistry, there are no polymer chemists, but this is because at least one, Paul J. Flory of Stanford University, prefers to think of himself as a physical chemist. Similarly, there are no analytical chemists, though Fred W. McLafferty of Cornell University, for example, who describes himself as an organic chemist, is one of those who have made mass spectrometry a routine analytical tool today.

Among 1000 most-cited scientists, 41 are Nobel Laureates

Name	Born	Field	Prize
Philip W. Anderson	1923	Physics	Physics, 1977
Christian B. Anfinsen	1916	Biochemistry	Chemistry, 1972
Julius Axelrod	1912	Pharmacology	Medicine, 1970
David Baltimore	1938	Virology	Medicine, 1975
Derek H. R. Barton	1918	Organic chemistry	Chemistry, 1969
Beruj Benacerraf	1920	Immunology	Medicine, 1980
Paul Berg	1926	Molecular biology	Chemistry, 1980
Baruch S. Blumberg	1925	Oncology	Medicine, 1976
Herbert C. Brown	1912	Organic chemistry	Chemistry, 1979
Jean Dausset	1916	Immunology	Medicine, 1980
Christian R. de Duve	1917	Cellular biology	Medicine, 1974
Gerald M. Edelman	1929	Immunology	Medicine, 1972
Ernst O. Fisher	1918	Organometallic chemistry	Chemistry, 1973
Paul J. Flory	1910	Physical chemistry	Chemistry, 1974
Sheldon L. Glashow	1932	Physics	Physics, 1979
Roger Guillemin	1924	Endocrinology	Medicine, 1977
François Jacob	1920	Molecular biology	Medicine, 1965
Bernard Katz	1911	Biophysics	Medicine, 1970
Har Gobind Khorana	1922	Organic chemistry	Medicine, 1968
Arthur Kornberg	1918	Molecular biology	Medicine, 1959
Hans A. Krebs	1900	Biochemistry	Medicine, 1953
Tsung-Dao Lee	1926	Physics	Physics, 1957
Fritz A. Lipmann	1899	Microbiology	Medicine, 1953
William N. Lipscomb Jr.	1919	Physical chemistry	Chemistry, 1976
Peter Mitchell	1920	Biochemistry	Chemistry, 1978
Jacques Monod	1910–76	Molecular biology	Medicine, 1965
Nevill F. Mott	1905	Physics	Physics, 1977
Daniel Nathans	1928	Microbiology	Medicine, 1978
Marshall W. Nirenberg	1927	Genetics	Medicine, 1968
Severo Ochoa	1905	Biochemistry	Medicine, 1959
George E. Palade	1912	Cellular biology	Medicine, 1974
Max F. Perutz	1914	Molecular biology	Chemistry, 1962
Burton Richter	1931	Physics	Physics, 1976
Frederick Sanger	1918	Molecular biology	Chemistry, 1958, 1980
Andrew V. Schally	1926	Endocrinology	Medicine, 1977
Earl W. Sutherland	1915–74	Pharmacology	Medicine, 1971
Howard M. Temin	1934	Oncology	Medicine, 1975
Steven Weinberg	1933	Physics	Physics, 1979
Geoffrey Wilkinson	1921	Organometallic chemistry	Chemistry, 1973
Robert B. Woodward	1917–79	Organic chemistry	Chemistry, 1965
Rosalyn Yalow	1921	Endocrinology	Medicine, 1977

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Chemists make up 27% of 1000 most-cited scientists

Field	Number
Biochemistry	84
Biophysics	26
Cardiology	33
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Garfield's staff spent two years and 750 hours of computer time to analyze 67 million literature references in 5 million published papers listed in *Science Citation Index*, which ISI also publishes. They sent questionnaires to some scientists asking them to name their fields and to furnish lists of their publications. This helped separate the work of those with identical last names and initials.

All authors on one paper were considered individually, because many principal investigators do not appear as first authors. "The average author in this study published 121 papers," Garfield says. "On 32 of these, his or her name appeared as first author and on 89 as one of the subsequent authors. The average author received 1178 citations to papers on which he or she appeared as first author and 2633 as coauthor. This clearly demonstrates the importance of all-author data for the most-cited scientists."

To guard against the influence of one paper that might have been cited an unusually high number of times, a statistician suggested that ISI delete citations to each author's most-cited paper. "We did so," Garfield says, "and found that 90% of the time, the most-cited paper accounted for fewer than 22% of the citations. In other words, the vast majority of the authors on this list would still remain among the most cited if their most-cited paper were removed.

"The fact is that scientists of Nobel class not only publish one or more superstar papers, they also publish more often, and their papers achieve higher impact," Garfield continues. "We observed this phenomenon over 15 years ago in a study of Nobel Prize winners." Garfield says that in the vast majority of cases, appearance on this list of 1000 most-cited scientists indicates that the person is of Nobel class, even if he or she has not won the prize.

Garfield points out that compared to the approximately 1 million scientists publishing at any time today, those on the list amount to 0.1%. Thus any apparent difference in "greatness" may be illusory.

The greatest number of citations in the literature of 1965 to 1978 was 17,679 to papers of immunologist Robert A. Good of Memorial Sloan-Kettering Cancer Center, New York City. The smallest number was 2432.

In coming issues of *Current Contents*, Garfield's essays will discuss the 1000 scientists by discipline, give detailed citation data and publication counts for each, identify academy memberships or other forms of recognition, and examine the institutions where highly cited research is going on.

Garfield had published in 1978 a list of the 300 most highly cited scientists. "It is obvious to me that we must extend these initial studies in the future to include at least another 1000 to 2000 scientists," he says. "I say this if only because the memberships of the world's academies of science exceed this number, and the number of important scientists exceeds that number."

Garfield expects expansion of the population to turn up most-cited scientists in smaller fields. Expansion also may diminish the persistent bias toward life scientists, who are many in number and whose papers tend to have large numbers of literature references. Garfield says the average number of references in a biochemistry paper is 30, for example, compared to 15 for mathematics.

He also plans studies of other fields outside the life sciences such as earth sciences and mathematics. These will eliminate differences among field sizes and practices in literature references. Studies assigning citations to

institutions will eliminate the weight given to some scientist-administrators whose names appear on large numbers of papers from their institutions, regardless of their contribution to the work.

Still, citation studies are sometimes abused and Garfield disapproves of their misuse. One chemist on the list of 1000 most-cited scientists tells C&EN that he regularly includes his citation counts on grant proposals, and that some deans use citations to determine faculty promotions and salaries. Another chemist also on the list says that his department never considers citations to decide on hiring or promoting faculty members.

Garfield says that ISI's list is one indication of which scientists are having the greatest impact on contemporary science. "However, one would have to examine the data for each individual on the list," he says, "in combination with other factors, to determine whether appearance on this list is due primarily to productivity, citation impact, or both. One cannot conclude that the most cited or most published author is necessarily the most important or the one who has made the greatest contribution to science." □

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Stellar region nearly empty of galaxies

As any casual stargazer would predict, the distribution of stars and galaxies in the universe is not uniform. Certain regions in space hold clumps and clusters of these objects, and others are relatively empty.

But even astronomers are surprised by new findings from three observatories that show just how uneven the distribution of galaxies is. A team of astronomers has found a huge region near the North Star that is nearly empty of visible galaxies. It covers 30° to 40° of the sky and takes up about 1% of the entire observable universe. In fact, it's large enough to hold about 2000 galaxies the size of the Milky Way.

The investigators are Robert Kirshner of the University of Michigan, Augustus Oemler Jr. of Yale University, Paul L. Schechter of Kitt Peak National Observatory, Arizona, and Stephen A. Shectman of Carnegie Institution's Mount Wilson, Calif., and Las Campanas, Chile, observatories. The region they have discovered includes part of the constellation Boötes and is in the same area of the sky as the handle of the Big Dipper but much farther away. It is not precisely empty, but the density of galaxies there is at least 10 times less than that for the universe as a whole.

"To have found a population density of less than three times the average would have been a rare find," Schechter says. "But finding that the density is about 10 times less than the average is exceedingly hard to understand."

The region puzzles Schechter and other astronomers because most of them accept the theory that the density of galaxies was fairly uniform just after the great explosion, or "big bang," that started the universe 10 billion to 20 billion years ago. Building from such a fairly uniform distribution, they had not predicted that such a vast region of space would be so empty.

However, Shectman says, the new discovery does not necessarily challenge the homogeneity of matter in the universe. For instance, the void may have begun as a region only slightly depleted in matter. Such a region would tend to grow and become emptier because its relatively low density would retard expansion of its volume only weakly. Also, gravitational effects would tend to pull mass from the region into denser neighboring regions. Another possibility is that mass is present in this apparently empty region, but it is in a form that is not visible to the astronomers—perhaps as a gas or in very small galaxies.

The astronomy team began an investigation of the large-scale distribution of galaxies several years ago. The team's method has been to examine in detail regions of the sky of about 2 square degrees. Because the universe is expanding, all distant galaxies appear to be traveling away from Earth. The speed at which they are moving gives an indication of how far away they are and is seen experimentally by a shift in their spectra toward shorter, red wavelengths. Thus, by examining the spectra of galaxies in a particular region, the astronomers put together a three-dimensional map of that region.

When they examined three areas near the North Star, they found that all but one of the more than 100 galaxies observed were either quite close or far away. There was a vast middle distance (corresponding to red shift values between 12,500 and 18,500 km per second) that contained only one visible galaxy. Statistically, such a region should have contained 25. □

1982 EMPLOYMENT OUTLOOK

Career Opportunities for Chemical Professionals

The status of the nation's economy in recent months has been decidedly uncertain. And some indicators suggest that the demand for chemists this year has not been so good as it was in 1980.

Reports from the nation's universities do not present a consistent picture of recruiting activity for graduating chemists and chemical engineers. At some schools, the number of employers who came to recruit graduating chemical professionals was less this year than last. At other schools, the situation was the reverse. About one thing, however, most schools seem to agree: The 1981–1982 academic year is expected to see lively recruiting activity by the employers of chemical professionals. The interviewing rooms in college placement facilities are rapidly being booked for the months immediately ahead.

As an indication that the demand for chemical professionals this year was not so brisk as it was last year, the volume of "positions open" advertising in C&EN is down this year. In 40 consecutive issues of C&EN starting in January 1981, the magazine carried 16% fewer column-inches of such advertising than in the first 40 issues of 1980.

A recent ACS salary survey shows that the starting salaries of inexperienced chemists and chemical engineers were greater this year than last. The median starting salaries of inexperienced chemists climbed 15% for B.S.'s, 7% for M.S.'s, and 12% for Ph.D.'s. The median starting salary of B.S. women chemists ($19,000) exceeded that of B.S. men chemists ($18,000).

These are some of the highlights of C&EN's latest survey of the employment picture for chemical professionals, as reported by senior editor Howard J. Sanders.

Do Chemists Need a Ph.D.?

Most chemists agree that it is highly desirable for chemists to acquire a Ph.D. degree if they seek a career in chemical research, especially basic research. For other chemically related careers, such as in sales, market research, and production, an M.S. or B.S. degree may be quite sufficient. **Page 42**

Demand

Employment opportunities for chemists and chemical engineers remain bright. Companies continue to recruit actively on college campuses for graduating chemical professionals. The unemployment rate among ACS members was 1.1% in March 1981—only slightly higher than the 0.9% last year. **Page 48**

Salaries

Experienced chemists and chemical engineers are earning more this year. Salaries also have increased for inexperienced chemical professionals who are recent graduates. But the salary increases of both groups are greatly reduced when the effects of inflation are taken into account. **Page 57**

Career Planning

A great deal of useful information and services on chemical careers is available from the American Chemical Society and from various other organizations. A directory in this section provides the names and addresses of many employers of chemists and chemical engineers. **Page 63**

Individual's goals determine whether an advanced chemical degree is necessary

Need a Ph.D.?

A question that just about every chemistry student or young graduate asks is: Should I go on to obtain an M.S. or Ph.D. in chemistry, or is a B.S. degree sufficient?

Everyone agrees that the answer to this question depends on the individual's career goals. A B.S. is adequate if a person wants to do relatively routine chemical work. In a development laboratory or possibly an applied research laboratory, an M.S. may be good enough. For basic research, however, a Ph.D. degree usually is essential.

Much depends, of course, on the size of the company for which a person works. Large firms are more apt than small ones to fill research jobs with Ph.D.'s. Much also depends on a company's traditional practices. In some companies almost all chemists working in applied research are Ph.D.'s. Union Carbide, for one, hires very few non-Ph.D.'s for research because it believes they lack scientific scope and depth.

John M. White, chairman of the chemistry department at the University of Texas, Austin, states, "If a student has no deep interest in solving complex chemical problems, I would not advise him to pursue an advanced degree. However, if a person has a driving desire to do chemical research at a fairly high level, he has almost no choice but to work toward a Ph.D."

Representatives of large companies agree almost unanimously that chemists who do not have Ph.D. degrees are at a very serious disadvantage in basic research. In all likelihood, they will not get the job or, if they do, will not progress very far.

Chemists who do not have both a Ph.D. and one or two years of postdoctoral research experience also will have a hard time getting a teaching and research job in a major university. Those with a Ph.D. but no postdoctoral experience, however, may get a position at a smaller, less prestigious school. Even with the best of credentials, a young Ph.D. chemist may find it difficult to obtain a position in any university these days because enrollments are declining and older teachers often have tenure.

Julius Axelrod, chief of the section on pharmacology at the National Institute of Mental Health, says. "You definitely need a Ph.D. to do research. It's sort of a union card. No matter how good you are, you've got to have the advanced degree."

Employers prefer Ph.D.'s for basic chemical research for several reasons:

- Basic research requires scientific skills and specialized theoretical knowledge possessed only by Ph.D. chemists.
- Research in basic chemistry demands creativity, intelligence, ability to work independently, and dedication more apt to be possessed by Ph.D. chemists than by those with lesser degrees.
- A Ph.D. degree from a highly regarded university is a "seal of official approval" indicating that its recipient can do high-quality basic research with little or no supervision.
- Most scientists doing basic research have Ph.D. degrees, and a Ph.D. can work and communicate with fellow Ph.D.'s more freely and effectively.

As Ted J. Logan, manager of Ph.D. recruiting at Procter & Gamble says, "You really need Ph.D. training to work independently in a basic research laboratory and to design your own experiments. An M.S. chemist may take several years to develop such ability. A chemist with only a B.S. degree finds it extremely difficult, if not impossible, to become an independent basic researcher. It does happen, but it's rare. In short, it is critically important to have a Ph.D. degree to do research at the forefront of science."

Gerald H. Brandt, manager for Ph.D. recruiting at Dow Chemical, says that Dow has increased its hiring of Ph.D. chemists noticeably since 1977, although in the seven years prior to 1977 it tended to favor B.S.'s and M.S.'s. The reason is Dow's growing emphasis on what it calls "long-range research," which is less theoretical than basic research and less immediately practical than applied research. Dow believes it needs to do more long-range research to develop the scientific know-how that will lead to significant technical innovations 10 or more years hence.

Monsanto also is placing increasing emphasis on the hiring of Ph.D. scientists. "We need Ph.D.'s," says Dale B. Fox, manager of university relations and professional employment, "because of the company's greater stress on developing new products and processes. Ph.D.'s can provide us with the added creativeness, scientific

White: You need a Ph.D. if you want to solve complex chemical problems

knowledge, and other attributes required for major technical advances."

Many observers, on the other hand, complain that some Ph.D. chemists are too highly specialized and want to continue doing in industry the research they did as graduate students. They are said to be inflexible and reluctant to switch to new positions where they are more needed. They also are said to be insufficiently dedicated to pursuing their company's research objectives.

"Many Ph.D. chemists working in corporate laboratories today are too university-oriented, rather than company-oriented," according to Wesley D. Bonds, a project leader in the chemical processes laboratory at Dow. "Almost obsessed with the details of basic chemistry, they care very little about the possible commercial applications of their research."

On the other hand, the fault is not necessarily that of the Ph.D. As one chemical research director puts it: "If a Ph.D. chemist is too theoretically oriented, it is primarily the fault of his management in not explaining to him adequately what his functions are or that his company's commercial goals are chiefly the production of salable, profitable products rather than the gathering of knowledge for its own sake."

Much less agreement exists as to whether applied chemical research also requires a Ph.D. Although many employers prefer Ph.D.'s for applied research, others think that M.S. chemists or highly competent B.S. chemists, especially those with considerable experience, can contribute to such programs. Work in applied research usually does not need as much knowledge of fundamental chemistry.

"Chemists in applied research do not need to know how to put elaborate molecules together," says Dow's Brandt. "They work with chemicals that other people already have creatively synthesized. Also, they are less likely to be working on the frontiers of science."

Although many Ph.D.'s have made careers in chemical development, M.S. and B.S. chemists also do this work. In development projects, it is quite common for M.S. and B.S. chemists to work side by side with chemical engineers who also have M.S. or B.S. degrees.

In some types of chemical work, having a Ph.D. actually can be a handicap. Thaddeus ("Ted") C. Ichniowski, chemistry professor at Illinois State University (currently on a one-year sabbatical at Dow Chemical), says that Ph.D.'s who want to work on product development work or in customer service for a small company may find themselves priced out of the market. "Similarly," he says, "a person who applies for a job teaching high school chemistry clearly would be overqualified with a Ph.D. Moreover, he [or she] might become quickly bored with the job because it lacks enough intellectual challenge."

Some observers are quite vocal in downgrading the master's degree. John Weikart, senior staff adviser in the employee relations division of Exxon Research & Engineering Co., says, "We do not hire M.S. chemists to do research because we do not believe they are qualified to perform the high-caliber work required by our organization."

The M.S. degree often is dismissed as a "consolation prize" for people who failed to qualify for a Ph.D. "We are very cautious about hiring M.S. chemists for research work," one corporate research director notes. "Many, we feel, will never be happy in such research because they were not permitted to get the Ph.D. training and thus do the Ph.D.-level work to which they so much aspired."

William P. Samuels, manager of Ph.D. recruiting at Union Carbide adds, "There is a common perception—whether justified or not—that an M.S. chemist is someone who was not successful in a Ph.D. training program and, therefore, will not be successful in a company's research program."

Others contend that this "common perception" often is too harsh. M.S. chemists should be recognized for the added knowledge and skills they have acquired and not exist somewhere in a no-man's land.

Many employers do give M.S.'s jobs with more responsibility than assigned to B.S.'s, recognizing that many M.S. chemists never intended to obtain a Ph.D. or were unable to do so because of financial, family, or other problems. Not all M.S.'s are "dropouts from a Ph.D. program."

Logan of Procter & Gamble says, "Industry realizes that M.S. chemists are both better equipped and more experienced professionally than B.S. chemists and pays them accordingly. They hire M.S. chemists for positions where they do not need the scientific depth of a Ph.D. but do need more than the depth of a B.S."

White of the University of Texas comments, "A lot of chemical positions can be filled just as well by

Logan: Ph.D. training is required to work independently in basic research

M.S.'s as by Ph.D.'s. In the years ahead, as the shortage of Ph.D. chemists grows, the demand for M.S.'s is certain to increase."

Some companies, in fact, prefer M.S. chemists for positions in which other companies would generally place a Ph.D. because they are less specialized and more flexible than Ph.D.'s. This is especially true when the individual has gone to a university that requires M.S. students to write a thesis based on original chemical research. Schools that require such practical training are held in far higher esteem than schools that do not.

Although conceding the value of an M.S. degree, Joseph T. Arrigo, manager of chemical products develop-

Ichniowski: Having a Ph.D. can be a handicap in some chemical work

ment for UOP's process division, urges that chemistry students, if at all possible, go on to get a Ph.D. degree if they want to do high-quality research in industry. "With a Ph.D. degree rather than an M.S.," he says, "you have a lot more going for you—and not just added prestige. The two or three years of extra work required to bypass the M.S. and go directly to a Ph.D. pay off enormously. You would be surprised at the number of M.S. chemists who are totally frustrated because they believe they have demonstrated superior performance but have not progressed as far as they should simply because they lack the 'Dr.' in front of their name."

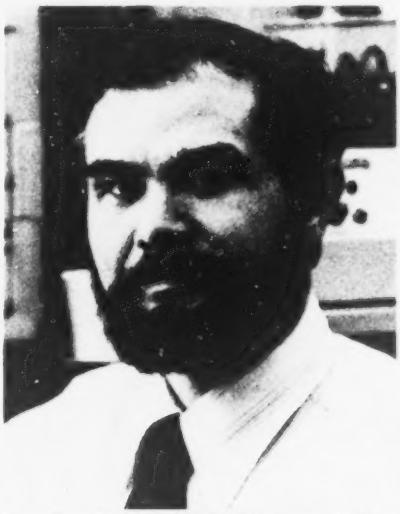
Fox of Monsanto adds, "A Ph.D. degree in chemistry gives you a much wider range of job opportunities than an M.S. It opens many more doors in the scientific and business worlds. Certainly, a student should make every effort to get a Ph.D. in chemistry rather than an M.S. On the other hand, if you want to become a chemical engineer, a B.S. or M.S. may be entirely sufficient."

In some small companies where research usually may not be sophisticated or innovative, a B.S. chemist eventually may rise to the position of research supervisor. But in other companies, lab work done by a B.S. chemist may not be much different from that done by a technician with only a high school diploma or one or two years of college work, not necessarily in chemistry. Obviously, to many B.S. chemists, this situation is discouraging.

Actually, some B.S. chemists have been very successful in research careers, including research management. Malcolm E. Pruitt, for example, received only a B.S. degree in chemistry from Abilene Christian College in 1941. In 1971, he rose to director of research at Dow Chemical. In 1978, he became director of R&D while continuing to serve as a vice president at Dow. Pruitt (now retired) did important research in his early years on vinyl and thermosetting polymers, polyglycols, and urethanes.

Robert P. Stambaugh, associate director of university relations at Carbide, declares, "Despite what some people may tell you, I believe that, if a B.S. chemist has ability, experience, and the ambition to grow as a scientist, he can rise to group leader or higher in a research organization. Of course, he has to be an exceptionally capable person."

Industry does hire many B.S. chemists to do conventional analytical testing or quality control work. They also may be employed in an applied research or development lab or carry out routine tasks for Ph.D. research chemists.



Lavallee: New Ph.D. chemists now seldom have difficulty finding jobs

Many career counselors recommend that after two or three years in the laboratory, B.S. chemists in a large company seek out new nonresearch jobs, in the company or with other employers, that still make use of their chemical knowledge. These could include work in chemical sales, market research, production, purchasing, plant safety, library services, or public relations.

Some B.S. chemists return to college either full time or at night to get M.S. degrees in some specialized area of chemistry or in such fields as business administration, chemical engineering, toxicology, environmental science, computer science, science writing, or patent law. Many companies give employees time off from work to attend daytime courses at a local university if the courses are relevant to their present or future work.

But what about B.S. chemists who want to remain in research but can advance only by getting a Ph.D.?

Most career guidance specialists recommend that an individual who has the ability, motivation, and financial resources should resign and go to school full time to obtain a Ph.D. An alternative is to continue working and take the lecture courses required for the Ph.D. degree at night or, on released time, during the day. This increases the length of time involved in getting the Ph.D. degree, but the student still is able to draw full salary from his or her employer. The employer usually will pay all or part of the cost of tuition and books.

However, about half of the time spent in getting a Ph.D. is devoted to research, normally done full time at the university (some companies allow employees to carry out some of their Ph.D. research in the company's laboratories). And the vast majority of Ph.D.-granting schools demand that Ph.D. candidates spend at least one year in residence. This forces the student who is working either to resign or take a leave of absence.

Companies vary in their policies regarding educational leaves of absence. Some pay a small stipend during the leave; others do not. Many guarantee a job will be available when the leave is completed.

As is obvious, getting a Ph.D. in chemistry while at least part of the time holding down an industrial job is quite difficult. Says one industrial research executive, "Only highly dedicated people can do it. The people who succeed are pretty rare."

Most advisers recommend that an individual who wants a Ph.D. should begin working toward it immediately after obtaining a B.S., before being burdened by family responsibilities and while able to concentrate fully on graduate study.

Many educators and industry people urge that students who are uncertain about a Ph.D. should take their undergraduate training at a school that has a co-op program alternating academic study with periods of work. Such a program gives the undergraduate a better idea of what life is like in the "real world."

Co-op students may find that production work is enjoyable and eventually want to become plant supervisors. Or they may be thrilled by work in a chemical laboratory or become convinced that they are really not cut out for a laboratory career and aim for some other type of job. Practical exposure to industry or the government also can be attained if an undergraduate gets a chemical job during the summer.

Among the benefits of a Ph.D. degree:

- Satisfaction in earning the highest degree possible for a chemist.
- Prestige among coworkers and with the general public.
- Broader and more challenging career opportunities, including the greater chance to direct the work of others.
- Larger salaries.
- Expanded opportunities for professional freedom.

• Greater chance to travel, attend scientific meetings, give scientific papers, and have articles and books published.

There is no doubt that Ph.D. chemists typically earn more money than B.S.'s. According to the latest salary survey of ACS members, the median annual salary of Ph.D. chemists in March 1981 was $35,000, 27% more than the $27,500 for B.S. chemists.

Any comparison of the lifetime earnings of a Ph.D. chemist with those of a B.S. would have to take into account the four or more years the Ph.D. spends in school while the B.S. is earning a professional income. On the other hand, Ph.D. tuition cost seldom enters the picture because most students studying for a Ph.D. in science have their tuition covered by a fellowship, grant, or teaching assistantship.

According to the latest ACS survey, also, the median salary of ACS-member M.S. chemists in 1981 was $30,000, only 9% greater than that of members with B.S. degrees.

Many chemists, however, argue that to obtain a Ph.D. rather than a B.S. solely because a Ph.D. chemist earns more money is very poor motivation. A person should become a Ph.D. chemist primarily because he or she likes chemistry, is good at it, and desires to contribute to science.

Alan L. McClelland, a personnel administrator in Du Pont's central research department, points out that undergraduates who are considering a Ph.D. should decide how important money is to them. If it is relatively unimportant and if they have no desire to become a Ph.D. for other reasons, perhaps they should venture only as far as a B.S. degree.

"People have different values," McClelland emphasizes, "and these values should be respected. Some people attach primary importance to their family life, recreational activities, community service, and other interests. Their tastes are fairly simple, and they do not place undue stress on money. Moreover, the heavy demands of Ph.D. research are clearly not for them."

Whatever the advantages of a Ph.D., the number of students who have received such degrees has been declining. New chemistry Ph.D.'s fell from 2208 in the academic year 1969–70 to 1518 in 1978–79. Surprisingly, the number of such new graduates rose to 1551 in 1979–80 and, according to one estimate, climbed still further to about 1560 in 1980–81. On the other hand, according to some

Baumgartner: As time goes on, importance of a degree tends to diminish

predictions, the number is expected to drop steadily from 1540 in 1981–82 to a mere 1300 in 1988–89. One reason is that total college enrollments are decreasing. Although the number of bachelor's degrees granted in chemistry increased every academic year from 1973–74 to 1978–79, the rise is attributed almost entirely to the growth in the number of students who were planning careers in medicine, dentistry, or other fields.

The decline in Ph.D. chemistry graduates also may reflect the adverse publicity given in the early 1970's to the problems chemists had encountered in getting jobs. Stories of new Ph.D. chemists sending out résumés to 100 or more employers and receiving job offers from none left an indelible and painful impression.

David K. Lavallee, associate professor of chemistry at Hunter College of City University of New York, comments, "Unfortunately, this now erroneous idea lingers on. The fact that new Ph.D. chemists currently have relatively little difficulty in finding jobs has not filtered down to vocational guidance counselors in the high schools and colleges. As a result, many students are shying away from careers in chemistry."

Another reason cited by Samuels of Carbide for the declining interest in chemistry, particularly at the Ph.D. level, "is the greater attractiveness of other careers, such as engineering, medicine, and business administration. Becoming number one on the corporate research totem pole is not as alluring as it once was."

Other observers claim that the dropoff in the number of new Ph.D. chemists is at least partly attributable to the growing belief that chemistry, at both the graduate and undergraduate levels, is a very tough subject. Only near-geniuses, it is believed, can hope to become proficient at it.

Clearly, in recent decades, the public image of chemistry as a profession has suffered significantly because of the widely publicized reports of chemicals as poisoners of humans and the environment. Back in the halcyon 1930's and 1940's, chemistry brought the world the breathtaking wonders of nylon, plastics, synthetic rubber, silicones, sulfa drugs, and cortisone. In more recent years, it has given the world such real or suspected horrors as thalidomide, Kepone, the dioxin 2,3,7,8-TCDD, dieldrin, aldrin, phenformin, Tris, hexachlorophene, bischloromethyl ether, and toxic chemical wastes.

As chemistry has become viewed more and more as an ominous threat to mankind, its appeal as a career has diminished. To what extent this has contributed to the decline in new chemistry Ph.D. graduates is difficult to assess. But the public's "antiscience syndrome" has had an unquestionably adverse impact.

In any event, the decrease in Ph.D. graduates, despite rising demand for them, makes it relatively easy for them to find jobs. It also tends to push up their salaries. Brandt of Dow points out that Ph.D. chemists today are in short supply and likely to become more so in the future.

But as Ichniowski of Illinois State University comments, "A Ph.D. degree in chemistry says something about your scientific ability but it does not ensure your professional success. Such success also depends a great deal on your attitudes toward your work and on your general personal traits."

Annette M. Baumgartner, manager of laboratory administration at Aerospace Corp. in Los Angeles, points out too that as chemists advance in their careers, the importance of their degree tends to diminish. After 10 years of professional work, people are much less concerned about whether a chemist has a B.S. or an M.S. degree. The main reason some chemists are recognized as Ph.D.'s is that they continue to be called "Dr."

More important than the degree, in the long run, she adds, are a person's professional accomplishments, personal qualities, and contributions to society. "By years of experience and by outstanding creativity," she adds, "a B.S. chemist may well surpass the achievements of an M.S. or even a Ph.D." □

Indicators suggest demand for chemists is good, but not so active as last year

Demand

Business activity in the chemical industry got off to a promising start in 1981, but in recent months it has seen a definite decline. This slowdown is reflected not only in a reduction in industry output but in, among other things, the demand for chemists. Although the demand for chemists in 1981 has been good, it generally has not been so brisk as it was last year—at least according to some indicators.

As one measure of demand, the volume of "positions open" advertising in C&EN from January 1981 through mid-September 1981 was less than that in the comparable period of 1980.

On the other hand, indications from college campuses are mixed. One leading school reports that the number of employers who interviewed its graduating chemistry students was less in academic year 1980–81 than in 1979–80. The average number of job offers received by its graduating B.S. and Ph.D. chemists was also less in 1980–81. Another major school, however, says that in 1980–81 more employers interviewed its graduating chemists than at any time in its history.

At the University of Wisconsin, the number of employers who interviewed graduating chemistry students declined from 85 in 1979–80 to 78 in 1980–81. Audrey L. Aylesworth, the university's chemistry placement coordinator, says that this decrease was not significant, however, and that the "level of recruiting activity for both years was pretty much the same."

She points out that the total number of interviews of graduating chemists rose from 906 in 1979–80 to 940 in 1980–81. She also indicates that some employers sent two interviewers to the campus in 1980–81 instead of the customary one, and some interviewers stayed two days at the university instead of the usual one day. As has been true for some years, employers were mainly from the chemical, petroleum, and, to a lesser extent, the pharmaceutical industries.

Apparently, the health of the nation's economy has not had a great effect on the recruitment of graduating chemists at the University of Wisconsin. "Despite the decline in automobile sales," she says, "we still get recruiters from General Motors, Goodrich, and other companies that are either in or related to the automobile industry."

B.S. chemistry graduates at Wisconsin got an average of 1.2 job offers in 1980–81, compared to 2.0 offers in 1979–80. Ph.D. chemistry graduates received an average of 2.6 offers in 1980–81, compared to 3.0 in the previous year.

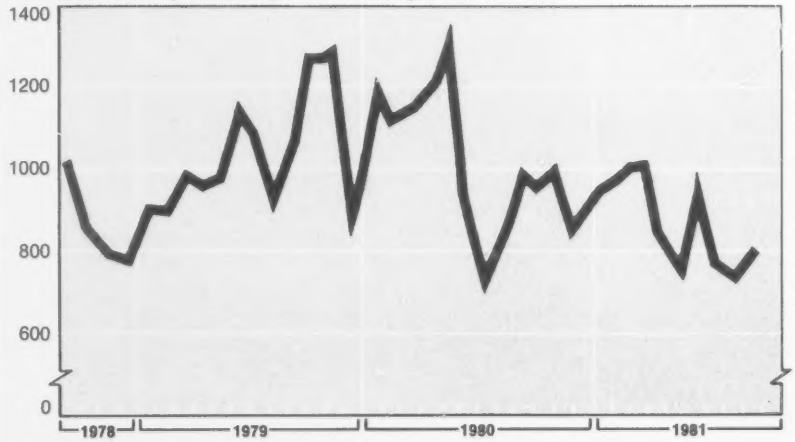
Aylesworth expects very active recruiting during the 1981–82 academic year, with an unusually large number of employers repesented. "Our regular companies," she explains, "have already signed up for 1981–82. Moreover, some companies that have never recruited here before or have not sent representatives in years have reserved interview dates."

Recruiting activity among graduating chemistry and chemical engineering students at the University of Illinois' school of chemical sciences in Urbana also was good in academic year 1980–81. The total number of student interviews was 4227 in 1980–81, compared to 4868 in 1979–80 and 3631 in 1978–79. Rebecca J. Simon, the school's placement director, says the data for 1979–80 were misleadingly high because the school that year graduated about 50 more B.S. chemical engineering students than usual.

The number of employer recruiting visits at the school was 227 in 1980–81, 210 in 1979–80, and 192 in1978–79. The number of man-days that

Recruitment advertising does not reach levels of 1980

Volume of C&EN "positions open" advertising, column-inches[a]



[a] Total volume of "positions open" advertising in four consecutive issues of C&EN ending with the issue specified. No issues were published in the last week of December 1978, 1979, and 1980.

employers spent interviewing on campus was 334 in the most recent academic year, compared to 425 in 1979–80 and 309 in 1978–79.

Over the years, Simon points out, roughly half of all new graduates of the University of Illinois' school of chemical sciences have taken jobs in the Midwest. What was striking in the past academic year was the marked increase in the proportion of graduates who accepted positions in the South, particularly in the Gulf Coast states, from 14% in 1979–80 to 31% in 1980–81. "I believe," she says, "that this change was brought about not so much by personal preference but by the growing availability of jobs in that area."

Simon says recruitment during the 1981–82 school year "promises to be at least as active as last year. The demand for our graduates is continuing, if not increasing slightly. About the same number of students have registered to use the placement office, and a similar number of employers have scheduled recruiting visits."

The number of employers who interviewed B.S. chemists at Purdue rose from 64 in 1979–80 to 70 in 1980–81, according to Richard A. Stewart, director of the university's placement service. During the same period, the number of employers who interviewed Purdue's M.S. chemists climbed from 34 to 54. And the number who interviewed its Ph.D. chemists increased from 26 to 48. More employers also interviewed graduating chemical engineers at all degree levels.

"As of now," says Stewart, "job prospects for our graduating chemists and chemical engineers in 1981–82 are good. Interviewing space in our placement facilities is booked solid from October through December, and we are rapidly making commitments for space for the early months of 1982."

The unemployment rate among American Chemical Society members last March 1 was 1.1%. This is only slightly higher than the 0.9% rate for March 1, 1980, which had been the lowest since ACS began conducting employment surveys in 1971. The highest level of unemployment among member chemists was 3.2% in the economically sluggish year 1972.

Unemployment among chemists is much lower than that among the total U.S. labor force, for which the rate last March was 7.3%. It also is lower than the 2.7% rate reported last March for all professional and technical employees.

The latest ACS survey shows that on March 1, 1981, 1.6% of member chemists with B.S. degrees were unemployed but seeking employment. The comparable figures were 1.2% for M.S. chemists and 0.8% for Ph.D.'s.

As has been true for some time, women chemists run a greater risk of becoming unemployed than do men. On March 1, 1981, 2.4% of women member chemists were unemployed but seeking employment, compared to only 0.9% for men.

In its latest Economic Survey Report, the American Institute of Chemical Engineers states that the unemployment rate among its members was 0.5% in February 1981. The figure was a very slightly lower 0.4% in February 1978, 1979, and 1980.

The median length of time that an AIChE member remained jobless, according to the institute's 1981 survey, was six months. This compares to three months reported in the 1979 survey and 11 months in 1980.

Another indicator of the demand for chemical professionals is the volume of "positions open" advertising in C&EN. In its first 40 issues of 1981, C&EN published 8962 column-inches

Employers continue to increase the number of chemical professionals on their staffs

In agreement with other employment indicators, a recent C&EN survey shows that demand for chemists and chemical engineers has been weaker in 1981 than in 1980. Responding organizations plan to hire fewer chemicals and chemical engineers this year than in the year previous.

In general, however, employers are optimistic about the employment outlook for chemical professionals over the next five years. The C&EN study indicates that 3% of the responding organizations regard the employment future of their chemists as excellent, 58% as very good, 33% as good, and the remaining 6% as fair. With respect to chemical engineers, 34% of the employers view their job outlook as excellent, 21% as very good, 31% as good, and the remaining 14% as fair or poor.

These are some of the findings of the latest C&EN annual survey of the hiring activities and plans of leading U.S. employers of chemists and chemical engineers. The survey covers 31 organizations (including a few research organizations) mainly in the chemical industry but also in such related fields as petroleum, rubber, pharmaceuticals, and food. At present, they employ about 14,600 chemists and 16,100 chemical engineers.

The organizations increased the number of both their chemists and chemical engineers 1% between mid-1980 and mid-1981. Between mid-1981 and mid-1982, they expect to expand the number of chemists they employ 2% and of chemical engineers 4%.

The respondents are hiring 10% fewer chemists in 1981 than in 1980. They also intend to hire 4% fewer chemists in 1982 than they did this year. The organizations also are hiring 6% fewer chemical engineers in 1981 than in 1980. In 1982, they expect to hire essentially the same number of chemical engineers as this year.

The majority of these new employees have been or will be recent college graduates. For chemists, the proportion of new employees who were new graduates was 59% in 1980 and 62% in 1981 and is expected to rise to 65% in 1982. For chemical engineers, the figures are 73% in 1980, 71% in 1981, and an anticipated 74% in 1982.

In their search for new chemistry graduates, employers are stepping up their recruiting visits to college campuses, although only modestly. Between academic years 1979–80 and 1980–81, the increase was 1%. Between 1980–81 and 1981–82, the anticipated rise is 4%. For chemical engineers, the increase in employer recruiting visits was 2% between 1979–80 and 1980–81 and is expected to be 4% in the present school year.

The chemical specialists in greatest demand this year are analytical, organic, and polymer chemists, as was the case last year. Also high on the list of specialists in particular demand are physical, inorganic, and catalysis chemists, as well as biochemists. Some employers express an interest in hiring chemists who are especially knowledgeable in coal, petroleum, rubber, food, and environmental chemistry.

In recent years, the representation of women among chemical professionals has been increasing gradually. Employers responding to C&EN's latest survey report that in 1981 12% of their chemists are women, the same level as last year; 13% are expected to be women in 1982. Among chemical engineers, the proportion who were women was 7% in 1980 and 8% in 1981; it is expected to be 8% also in 1982.

Degrees awarded in chemistry in 1979–80 decreased at B.S. and M.S. levels but rose for Ph.D.'s

Academic year	Degrees awarded in chemistry[a]			Degrees awarded in chemical engineering		
	Bachelors	Masters	Ph.D.'s	Bachelors	Masters	Ph.D.'s
1969–70	11,617	2146	2208	3720	1045	438
1970–71	11,183	2284	2160	3615	1100	406
1971–72	10,721	2259	1971	3663	1154	394
1972–73	10,226	2230	1882	3636	1051	397
1973–74	10,525	2138	1828	3454	1045	400
1974–75	10,649	2006	1824	3142	990	346
1975–76	11,107	1796	1623	3203	1031	308
1976–77	11,322	1775	1571	3581	1086	291
1977–78	11,474	1892	1525	4615	1237	259
1978–79	11,643	1765	1518	5655	1149	304
1979–80	11,446	1733	1551	6383	1271	284

a Does not include biochemistry and geochemistry. **Source:** Department of Education's National Center for Education Statistics

of such advertising, down from 10,374 in 1979 and 10,663 in 1980. The most recent data indicate a drop of 16% in column-inches between the 40 issues in 1980 and the 40 in 1981.

Demand for all types of technical personnel is reflected in the High Technology Recruitment Index compiled by Deutsch, Shea & Evans, a New York City consulting firm. This index is based on the volume of technical recruitment advertising in a large number of newspapers and magazines.

Some concern was aroused in scientific and engineering circles early this year when the index (a three-month running average) dropped from 142 in February to 135 in April and to 132 in May. However, the index started climbing slowly to 135 in June and 137 in July. It is expected to rise further for August.

A possible barometer of the demand for chemists and chemical engineers is the activity at the Employment Clearing House at ACS's fall 1981 national meeting in New York City, compared to the activity at the society's fall 1980 national meeting in Las Vegas, although the two meetings were not really comparable.

Because more chemists and chemical engineers live near New York City than Las Vegas, employers could anticipate higher participation in the clearinghouse in New York and were more likely to send recruiters there. Attendance at the Las Vegas meeting was reduced too, by the last-minute shift of the meeting there from San Francisco because of a prolonged hotel strike. More comparable to the meeting in New York was the fall 1979 national meeting in Washington, D.C., a city which also is accessible to large numbers of chemists and chemical engineers and to potential employers.

The number of employer representatives who used the Employment Clearing House was 300 in New York, 209 in Las Vegas, and 368 in Washington. The number of job applicants was 697 in New York, 356 in Las Vegas, and 589 in Washington. The number of positions listed for candidates' review totaled 484 in New York, 375 in Las Vegas, and 536 in Washington. The total number of job interviews at the three meetings was 2336, 1165, and 2279, respectively.

Of particular interest is the fact that the average number of interviews per job candidate was 3.4 in New York, 3.3 in Las Vegas, and 3.9 in Washington. These figures were decidedly better than the 2.3 interviews per candidate reported by ECH at the fall 1975 national meeting in Chicago.

Audra B. Rafter, manager of the ACS Employment Aids Office, which operates ECH, points out that, as is usually the case, the greatest number of positions (110) listed at the latest clearinghouse was for analytical chemists. The runnersup at the New York meeting were organic chemists (74 openings), polymer chemists (64), chemical engineers (50), physical chemists (27), biochemists (20), and inorganic chemists (19). The number of openings for chemical engineers rose from fifth place at the Las Vegas clearinghouse to fourth place in New York. On the other hand, the number of positions for biochemists slipped from fourth place in Las Vegas to sixth in New York.

Data from the College Placement Council, Bethlehem, Pa., on job offers made to graduating students in 161 colleges and universities show that candidates for B.S. degrees in chemistry received 4% fewer job offers during the 12 months ending June 1981 than during the previous 12 months. Inexperienced candidates for M.S. degrees in chemistry got 8% more offers in 1980–81 than in 1979–80, and Ph.D. candidates got 1% more offers.

B.S. chemical engineering students received 6% more job offers in 1980–81 than in 1979–80. Inexperienced M.S. candidates received 14% fewer offers, and Ph.D. candidates got 9% more offers.

In 1980–81, B.S. chemical engineering students, says CPC, got substantially more job offers than B.S. chemistry students—7428 compared to 409. The reason, in part, is the far greater demand for chemical engineers than for chemists at the B.S. level. In addition, a much higher percentage of B.S. chemical engineers than chemists begin employment immediately after graduation. Many B.S. chemists plan to go on to advanced study.

The council also reports that men candidates for B.S. degrees in chemistry got 2% more job offers in 1980–81 than in 1979–80, but women candidates got 12% fewer job offers. This situation differs noticeably from the previous year; number of job offers to B.S. men was 6% higher in 1979–80 than in 1978–79, whereas offers to B.S. women increased a phenomenal 24% in that period.

The availability of chemists is greatly affected, of course, by the number who graduate each year. The Department of Education's National Center for Education Statistics reports that the number of B.S. degrees awarded in chemistry dropped from 11,643 in academic year 1978–79 to 11,446 in 1979–80. This reverses the steady increase that had prevailed since the early 1970's. Another trend was reversed when the number of Ph.D.'s awarded in chemistry rose from 1518 in 1978–79 to 1551 in 1979–80, after a decline every year from 1969–70 to 1978–79.

Also noteworthy is the sharp increase in the number of B.S. chemical engineering degrees awarded in recent years. The figure climbed 23% between 1977–78 and 1978–79 and rose another 13% between 1978–79 and 1979–80. The 6383 B.S. chemical engineering degrees awarded in 1979–80 were 1.7 times greater than the number awarded in 1969–70. Although some observers worry that universities now are turning out too many chemical engineers, many employers say that supply definitely falls short of demand. □

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Chemists' salaries are rising, although gains are diminished sharply by inflation

Salaries

Between March 1980 and March 1981, the median annual salaries of experienced chemists increased 10% for those with B.S. degrees, 15% for M.S.'s, and 12% for Ph.D.'s. In 1981, the starting salaries of inexperienced chemists climbed 15% for B.S.'s, 7% for M.S.'s, and 12% for Ph.D.'s.

When inflation is taken into account, however, the median annual salary of experienced B.S. chemists remained essentially unchanged between 1980 and 1981 and that of inexperienced M.S. chemists decreased. Also because of inflation, the salaries of other types of experienced and inexperienced chemists increased only modestly.

These are among the results of two annual salary surveys conducted this year by the ACS Office of Manpower Studies. One survey, which deals with the salaries of experienced chemists and chemical engineers who are ACS members, was issued in July as Salaries 1981 (C&EN, June 22, page 56). The other survey covers the salaries of inexperienced chemistry and chemical engineering graduates (those with 12 months or less of professional experience), many of whom are not ACS members. The results of this survey will be published next spring as Starting Salaries 1981.

Data for the 1981 salary survey of experienced chemists and chemical engineers came from more than 11,000 members who responded to an ACS questionnaire. The median annual salary of B.S. chemists who are ACS members rose from $25,000 on March 1, 1980, to $27,500 on March 1, 1981. In this same period, the median annual salary of M.S. chemists increased from $26,000 to $30,000, and the median for Ph.D. chemists climbed from $31,200 to $35,000. The median for all chemists rose from $28,900 to $32,000.

The ACS survey also shows that the median annual salary of B.S. chemical engineers increased 3% from $35,000 on March 1, 1980, to $36,000 on March 1, 1981. In this period, the median for M.S. chemical engineers climbed 14% from $35,000 to $40,000. For Ph.D. chemical engineers, the figures rose from $38,000 to $42,000, a gain of 11%. For all chemical engineers, the median salary climbed 9% from $36,000 to $39,200. Thus, the overall median salary of chemical engineers ($39,200) on March 1, 1981, was 23% higher than that of chemists ($32,000).

The American Institute of Chemical Engineers says that the median annual salary of its members at all degree levels increased 10% from $31,000 in February 1980 to $34,000 in February 1981. This compares to an increase of only 5% between 1979 and 1980.

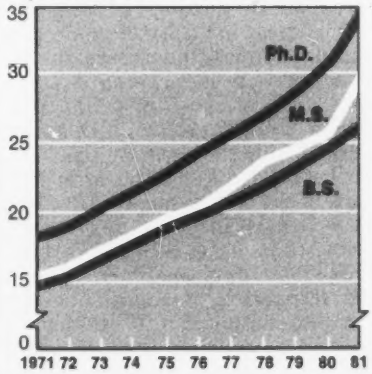
For some years, the median annual salaries of AIChE members have been less than those of ACS-member chemical engineers. One reason is that members of AIChE are, on the average, younger and therefore less experienced than ACS-member chemical engineers.

When the factor of inflation is taken into account, the increases in the median salaries of ACS-member chemists between March 1980 and March 1981 (ranging from 10 to 15%, depending on degree level) do not look particularly impressive. The Bureau of Labor Statistics' consumer price index rose about 10.5% between March 1980 and March 1981. Hence, the gain in the median salary of ACS-member B.S. chemists was, in effect, wiped out by inflation. The gain for M.S. chemists was slashed to less than 5% and that for Ph.D.'s to less than 2%.

The salaries of chemists are affected, of course, by a variety of factors, such as the type of employer for which they work. In March 1981, Ph.D. chemists, for example, received a median annual salary of $39,000 in private industry, $36,300 in the government, and $26,200 in colleges and universities.

Salaries of experienced B.S. chemists rose 10% in 1981

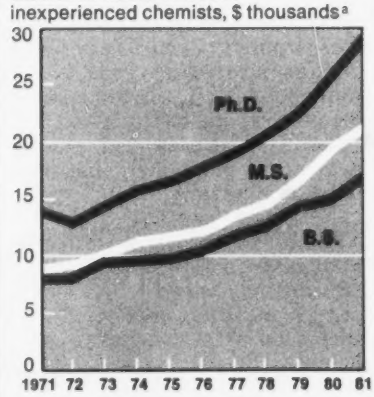
Median annual salaries of experienced chemists, $ thousands[a]



a Chemists with more than 12 months of professional experience; data as of March of each year.
Source: ACS comprehensive salary surveys

Chemists' starting salaries climbed at all degree levels

Median annual salaries of inexperienced chemists, $ thousands[a]



a Chemists with 12 months or less of professional experience; data as of about June of each year.
Source: ACS starting salary surveys

How does employee income compare in different fields?

To put the salaries of chemists into suitable perspective, it is worthwhile to compare these incomes with those received by other professionals. Unfortunately, comparisons of this type are difficult to make because equivalent information is not available for many types of work. A number of organizations, however, do publish salary data that are useful in suggesting the earning levels in various fields.

The American Medical Association, for example, reports that the average net income (the average gross income less professional expenses) of physicians from their medical practice in 1979 was $78,400 (latest available figure). The American Dental Association says that the average net income of dentists from their professional practice in 1978 was $48,363 (latest available figure). The American Institute of Physics says that the average salary of the members of the organizations that constitute AIP (most of whom are physicists) was, according to a preliminary estimate, $36,500 in May 1981.

The Department of Labor's Bureau of Labor Statistics annually compiles information on the salaries of workers in a number of white-collar occupations in private industry. These data are collected by BLS mainly to determine whether the salaries that the government pays its employees are competitive with those paid in industry. The data allow general comparisons to be made between the industrial salaries earned in various occupations at different levels.

	Average annual salary[a]
Attorneys, upper level	$66,958
Engineers, upper level	56,828
Chief accountants, upper level	56,016
Personnel directors, upper level	53,914
Chemists, upper level	48,845
Accountants, upper level	43,754
Chief accountants, starting	31,576
Engineers, middle level	31,352
Chemists, middle level	30,801
Personnel directors, starting	27,848
Attorneys, starting	22,477
Engineers, starting	21,712
Chemists, starting	18,092
Accountants, starting	16,529

a As of March 1981, excluding overtime and nonproduction bonuses, but including cost-of-living bonuses and incentive earnings. **Source:** Department of Labor's Bureau of Labor Statistics

In industry, the median annual salary for B.S. chemists in March 1981 was $30,000 for men and $21,500 for women, for M.S. chemists $32,500 for men and $27,200 for women, and for Ph.D. chemists $39,700 for men and $31,000 for women.

Traditionally, salaries of women chemists have been lower than those of men. One reason is that women chemists tend to be younger and therefore less experienced than men chemists. The median age of employed women belonging to ACS is 35; it is 41 for employed men. Furthermore, women chemists are less apt than men to have typically high-paying jobs, such as in management, and are less likely to have a Ph.D. degree. Another factor is that women chemists are more likely than men to spend time, at irregular intervals, out of the work force.

The 1981 ACS starting salary survey, based on replies from close to 3800 inexperienced chemists and chemical engineers, indicates that the median annual starting salary of B.S. chemists working full time is $17,200 this year, compared to $15,000 last year.

For M.S. chemists, the median climbed to $21,300 from $20,000 in 1980. And for Ph.D. chemists, the figure increased to $29,500 from $26,400 last year.

As usual, starting salaries of inexperienced chemical engineers exceed those of chemists. The median for B.S. chemical engineers working full time increased 13% from $21,600 in 1980 to $24,400 in 1981.The median for M.S. chemical engineers rose 9% from $23,900 in 1980 to $26,000 in 1981. The median for Ph.D. chemical engineers rose in this period from $28,800 to $31,500, a gain of 9%.

Median salaries of both chemists and chemical engineers are affected by the type of employer. The medians for inexperienced full-time B.S. chemists in 1981 were $18,600 in manufacturing industry, $17,900 in nonmanufacturing industry, and $12,300 in federal, state, and local governments.

Median starting salaries of full-time B.S. chemical engineers were $24,600 for those working in manufacturing industry, $24,000 in nonmanufacturing industry, and $19,700 in federal, state, and local governments.

In recent years, the median starting salaries of B.S. women chemists and chemical engineers in industry (quite unlike the situation in years previous) either exceeded those of their male counterparts or were very close. In 1980, B.S. women chemists received a median starting salary of $16,750, compared to $16,800 for men chemists, and B.S. chemical engineers got $21,900 if they were women and $21,700 if men. This year, B.S. women chemists got a median starting salary of $19,000, whereas their male counterparts got $18,000. Also this year, B.S. women chemical engineers received a median starting salary of $24,700, and men chemical engineers received $24,500. Companies have been attempting to increase the representation of women on their staffs by paying them higher salaries than men in the competition to do so.

The ACS survey also indicates that 44% of inexperienced B.S. chemists in 1981 were employed full time in the chemical profession. In addition, 40% had graduate assistantships or fellowships, 14% were working full time in nonchemical jobs, and 1% were unemployed but not seeking employment. Less than 1% were unemployed and seeking employment.

Among inexperienced Ph.D. chemists, 64% were employed full time in the chemical profession, 31% had postdoctoral fellowships, and 5% were working full time outside the chemical profession. None of the survey respondents with Ph.D.'s were unemployed.

The job picture for Ph.D. chemists definitely has improved since the mid-1970's, when some had great difficulty finding chemical employment. Only 44% of inexperienced Ph.D. chemists were working full time in the chemical field in 1976. Moreover, the percentage of new Ph.D.'s who do postdoctoral work (sometimes because they cannot obtain other chemical employment) decreased from 49% in 1976 to 24% in 1979 before increasing to 31% in 1981.

The great majority of newly graduated chemical engineers in 1981 have jobs in the chemical profession—79% of the B.S.'s, 70% of the M.S.'s, and 95% of the Ph.D.'s. Some work outside the chemical field—13% of the B.S.'s, 6% of the M.S.'s, but none of the responding Ph.D.'s. Some have assistantships or fellowships—8% of the B.S.'s, 23% of the M.S.'s, and 5% of the Ph.D.'s. None of the responding chemical engineers were unemployed and seeking employment, and less than 1% of the B.S. chemical engineers and none of the responding M.S.'s and Ph.D.'s were unemployed but not seeking employment. □

NOTE

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Chemical & Engineering NEWS

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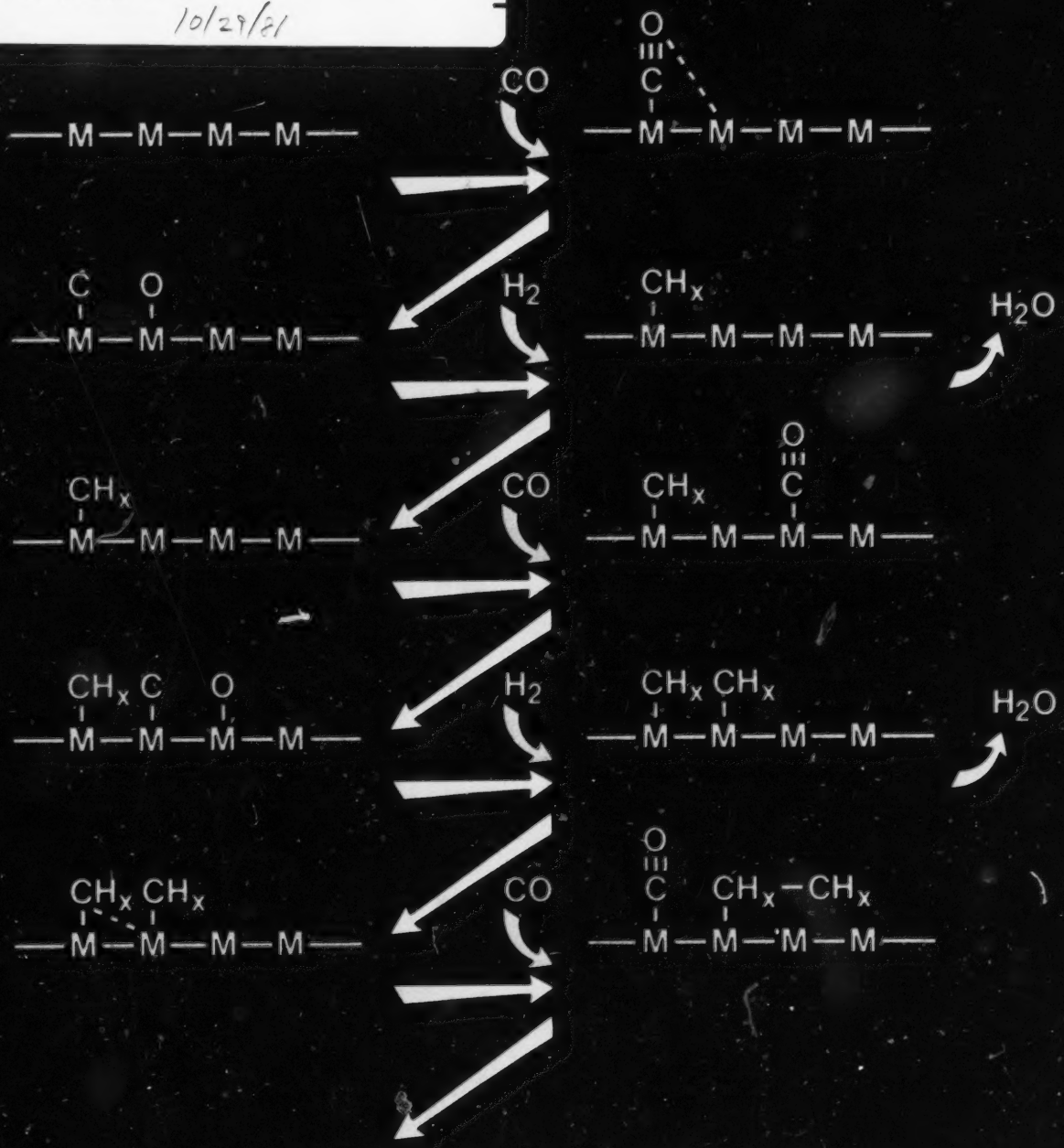

Fischer-Tropsch chemistry struggles toward commercialization

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News of the Week

- ***Nobel prize in chemistry*** *awarded for work in frontier orbital theory and conservation of orbital symmetry; physics prize recognizes spectroscopy research.* ***Page 6***
- ***Carbon dioxide buildup*** *in the atmosphere qualitatively related to recent climatic changes, study finds.* ***Page 7***
- ***Environmental groups seeking ouster*** *of Interior Secretary Watt gave Congress petitions bearing 1.1 million signatures.* ***Page 7***
- ***Nuclear fuel reprocessing facility*** *at Barnwell, S.C., will be shut down by co-owners.* ***Page 8***
- ***U.S. chemical company third-quarter earnings,*** *though up 5 to 10% overall on a sales increase of 10%, were still disappointing as profit margins slipped.* ***Page 8***

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- ***Lithium producers increase U.S. capacity*** *and look into South American deposits, spurred by growing uses in aluminum, glass, ceramics, and lubricant industries.* ***Page 11***
- ***Styrene will grow at 6%*** *average annual rate through 1985, but most growth will be outside U.S., study says.* ***Page 13***

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- ***Mycotoxin's presence in leaf samples*** *from Southeast Asia, analyzed by expert in fungal toxins, supports U.S. contention of chemical warfare.* ***Page 15***
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- ***Fatty acids spontaneously oxidize*** *by three competing pathways, yielding products that are similar to biologically active products of enzymic oxidation.* ***Page 18***

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ACS News

- ***Tour speakers*** *for November listed; ACS-organized health shows aired on TV; ACS wins grant to prepare high school science course; junior high science enrichment program in production.* ***Page 37***

O'Neill Jr. (D.-Mass.) and Sen. Alan Cranston (D.-Calif.). Rep. O'Neill said the petitions would have some impact on Congress and on the Reagan Administration. Sen. Cranston, who voted against Watt's nomination, called Watt "a puppet of . . . exploiters," and his policies "reckless and irresponsible."

Watt, who was on a fund-raising trip for the Republican party, was not available for comment. But supporters of the Interior Secretary in the Senate, namely Ted Stevens (R.-Alaska) and Strom Thurmond (R.-S.C), called this latest act of "environmental extremists" an attempt to influence reporters through a "media blitz." □

Barnwell nuclear fuel plant to be closed

Allied Corp. together with its partner General Atomic Co. have finally decided to shut down their nuclear fuel reprocessing facility in Barnwell, S.C. Unless some business group or consortium comes forward to purchase the plant before October 1982, it will be closed.

Allied puts the blame for the closing on the decision made by President Carter in April 1977 to ban indefinitely any nuclear fuel reprocessing in the U.S., effectively prohibiting the Barnwell plant from performing its planned purpose. For several years after that, until 1980, Allied negotiated with the government for the purchase of the facility as an away-from-reactor storage site to alleviate the growing problem of spent fuel congestion at nuclear reactors.

Since that time, Allied says, although Congress has continued to fund some R&D work at the plant, it has become increasingly clear that under present laws private industry financing of a nuclear reprocessing plant is not feasible. Most firms in the nuclear industry and the electric power industry conclude, Allied adds, that fuel reprocessing will have to be done by the federal government, as it is done in other nations with such facilities.

President Reagan's recent policy statement on nuclear power (C&EN, Oct. 9, page 8) was not a major factor in the decision to close the plant, but it helped. There had been considerable confusion about whether the government would purchase the Barnwell plant. However, Reagan's message was that private industry should be the sector that finances reprocessing plants, ending any speculation of more government support.

A big factor in the decision, Allied says, was the definite possibility that any new Administration in the White House could return to the policy of banning nuclear fuel reprocessing, closing Barnwell again. Also, there was the uncertainty about getting a license for a reprocessing plant from the Nuclear Regulatory Commission. Finally, a number of other regulatory and technical problems would have to be solved before any actual reprocessing could begin.

Allied's third-quarter earnings include a reserve that will be used to cushion the loss from closing the plant. The plant is valued at about $105 million and more than $362 million has been spent in its design and construction since it was started in 1970. □

Barnwell plant will be shut down by Allied and partner General Atomic

Chemical earnings up a bit in third quarter

With an easy shot at better performance compared to recession-racked 1980, the U.S. basic chemical industry has to mark down the third quarter of 1981 as a disappointment. Results went all over the lot this time, from considerably improved to worse than before. Overall, companies reporting to date show third-quarter earnings up 5 to 10% on a sales increase of about 10%. In other words, profit margins still slipped.

That's scarcely what the industry had expected. The standard vision of the year's second half called for a brisk improvement following a sluggish first half. The actual outcome was somewhat the reverse. After some signs of a pickup in the first quarter, business planed off in the second and then skidded a bit in the third.

Since a continued slump looks likely for the fourth quarter, the year as a whole will fall far short of earlier expectations. The full-year profit gain will be lucky to make 10%, and might easily turn out to be less.

"The improvement in the U.S. economy that most business and government economists expected in the second half of 1981 simply has not yet materialized," says Robert M. Keil, financial vice president at Dow Chemical.

He should know. Dow's unusually high stake in European markets and U.S. petrochemicals placed it right where trouble was worst in the third quarter. The result was the industry's sharpest profit drop, 32% from 1980, on a sales gain of 16%. Dow's profit margin fell to 3.7% from 6.4% a year ago.

Elaborating on the third-quarter bath, Dow echoes other companies in pointing to major culprits in the U.S.: weak markets in the important areas of automobiles and housing. Also slashing U.S. earnings was cut-throat competition in basic petrochemicals and organic intermediates. Dow says that such pressure drove down profit margins on big-volume intermediates such as vinyl chloride, ethylene oxide, and ethylene dichloride.

Most firms had a third-quarter earnings gain, but a few big ones didn't

	Third-quarter 1981						Nine-months 1981					
			Change from 1980		Profit margin[b]				Change from 1980		Profit margin[b]	
	Sales	Earnings[a]	Sales	Earnings	1981	1980	Sales	Earnings[a]	Sales	Earnings	1981	1980
Air Products	$ 403.0	$ 28.8	9%	24%	7.1%	6.3%	$1203.6	$93.7	9%	11%	7.8%	7.6%
Akzona	288.2	5.0	21	def	1.7	def	911.1	12.5	18	346	1.4	0.4
Allied Corp.[c]	1544.0	80.0	17	21	5.2	5.0	4711.0	251.0	16	21	5.3	5.1
American Cyanamid[d]	868.0	42.0	9	4	4.8	5.0	2513.7	131.3	7	19	5.2	4.7
Celanese	955.0	34.0	22	55	3.6	2.8	2868.0	111.0	18	34	3.9	3.4
Diamond Shamrock	823.4	51.8	6	4	6.3	6.4	2523.3	163.5	10	3	6.5	6.9
Dow Chemical	2923.9	108.5	16	−32	3.7	6.4	8887.7	418.4	13	−26	4.7	7.2
Ethyl Corp.	448.2	20.7	4	9	4.6	4.5	1326.9	65.1	1	nc	4.9	5.0
B. F. Goodrich[e]	822.2	13.7	5	57	1.7	1.1	2431.1	42.6	6	9	1.8	1.7
W. R. Grace	1587.6	97.1	6	41	6.1	4.6	4761.5	279.6	8	28	5.9	5.0
Hercules	690.0	27.0	19	21	3.9	3.8	2070.0	96.1	12	16	4.6	4.5
International Minerals	448.3	39.9	3	−1	8.9	9.3	1531.9	116.7	10	−8	7.6	9.1
Monsanto[f]	1633.8	55.9	6	89	3.4	1.9	5389.4	325.7	10	5	6.0	4.4
Olin	489.9	17.7	13	46	3.6	2.8	1556.2	79.1	11	29	5.1	4.4
Pennwalt[g]	287.5	9.1	0	0	3.2	3.2	891.1	29.5	3	−6	3.3	3.6
PPG Industries	847.5	49.7	11	4	5.9	6.2	2550.0	166.2	10	17	6.5	6.1
Rohm & Haas[h]	448.0	21.6	11	−4	4.8	5.6	1472.1	73.9	13	−4	5.0	5.9
Stauffer Chemical	343.3	14.3	4	218	4.2	1.4	1349.8	125.3	6	33	9.3	7.4
Thiokol	178.9	9.2	9	42	5.1	4.0	529.0	26.2	15	12	5.0	5.1
Union Carbide	2424.7	137.8	2	−10	5.7	6.5	7739.2	509.2	6	−3	6.6	7.2

a After-tax income from continuing operations, excluding nonrecurring and extraordinary items. b After-tax income as a percentage of sales. c Excludes net nonrecurring gain of $38 million. d Includes nonrecurring charge in 1980. e Excludes nonrecurring gains of $8.9 million in third-quarter 1981 and $31.1 million in nine-months 1981. f Excludes $67.7 million nonrecurring gain in third-quarter 1981. g Excludes results of discontinued operations and a nonrecurring gain of $17.0 million in nine-months 1981. h Includes nonrecurring charge in nine-month 1981. **def** = deficit. **nc** = no change.

Then there's the foreign situation. Although business improved in many parts of the world for many companies, the all-important European market was terrible. Generally, Dow says that the strengthening of the dollar against foreign currencies and recessed economic conditions in many other countries contributed to lower profits.

"Strengthening of the dollar" (which hurts exports and lowers dollar-reporting of sales in foreign currencies) is a common lament for other companies in explaining weakened foreign earnings. This factor was important, for example, in cutting Union Carbide's overall third-quarter earnings 10% from a year ago.

Carbide has posted some arresting figures. Its export sales from the U.S. were down 28% year-to-year in the third quarter and down 18% from the second quarter. The company's European sales tumbled 31% from a year ago.

One startling, and important, example of what is happening in export markets is fertilizer. With the exception of Hooker Chemical's revived superphosphoric acid shipments to the Soviet Union (C&EN, May 4, page 4), fertilizer exports are down from their prosperous levels of 1980.

At International Minerals & Chemical, a top fertilizer producer, chairman Richard A. Lenon says, "High interest rates are hurting the fertilizer business in all markets, and the rapid increase in the price of the U.S. dollar is having a very negative impact on exports. Foreign exchange limitations continue in Poland and other East Bloc countries, along with some other areas, particularly Brazil." With sales off, Lenon continues, phosphate chemical prices declined sharply, and IMC, along with most other producers, has announced cutbacks.

American Cyanamid, another company in the fertilizer market, has much the same report on phosphates, calling them "severely depressed." Chairman James G. Affleck says that lower prices and unit volume in phosphate fertilizer resulted in a substantial drop in operating (pretax) earnings of the company's agricultural products business.

Obviously, things weren't all bad in the third quarter, since many companies had double-digit earnings gains from third-quarter 1980. In some cases, as in synthetic fibers at Akzona, Celanese, and Monsanto (Du Pont not having yet reported), simple recovery from last year's recession explains the progress. Even so, profit margins in fibers are still very low in many types.

In other cases, however, chemical products are doing very well by any standard. Part of the reason is the extensive efficiency gains at chemical plants in the past five years. Olin chairman John M. Henske says, "Our continuing efforts at improving plant yields are paying off." Olin's earnings jumped 46% in the third quarter from a year ago.

Another reason is the specialized nature of many chemical lines, which enables them to resist ups and downs in the economy. For example, Carbide and Air Products report strong gains in the third quarter for industrial gases.

Stauffer Chemical says the same thing about its specialty chemicals and food ingredients. Dow and Cyanamid cite booming business in oilfield chemicals.

For the rest of 1981, the chemical industry has put out warning signs. A typical cautious comment comes from the chairman of Hercules, Alexander F. Giacco: "We do see signs of weakening in most of our business areas as customers hesitate to build inventories. It would appear that the economy may well be flat in the next few months until the current uncertainties are resolved." □

Lithium producers gear up for bright future

Growth in glass, ceramic, and lubricant applications and use in aluminum production spur U.S. capacity expansion, South American development

Stephen C. Stinson
C&EN, New York

Lithium and lithium compounds have advanced in the past decade from specialty to commodity status in world industry. The future holds bright—if distant and uncertain—prospects for use in new energy sources. As a result, the two U.S. producers who together supply 75% of world lithium needs have expanded U.S. production capacity and have begun looking to the salt flats of South America for future supplies.

Lithium Corp. of America, a subsidiary of Gulf Resources & Chemical Corp. located in Gastonia, N.C., has just completed an $18 million expansion of its mine and mill near Cherryville, N.C., and of its Bessemer City, N.C., chemical plant from 2300 to 2900 tons per year of lithium metal equivalent. Meanwhile, Foote Mineral Co., Exton, Pa., expanded its King Mountain, N.C., facilities from 980 to 1300 tons per year in 1979 and reports that the operation ran at a profit in 1980 for this first time since it was opened in 1976. Foote is a publicly held company, 89% owned by Newmont Mining Co.

Foote has produced lithium chemicals from brines at Silver Peak, Nev., since 1966. But the company also is planning development of a vast, lithium-rich brine deposit under the Salar de Atacama salt flat in Chile, 420 miles south of La Paz, Bolivia. In August 1980, Foote joined the Chilean government's Corporacion de Fomento de la Produccion (CORFO) in setting up a joint venture company, Sociedad Chilena de Litio, in which Foote has a 55% interest. Foote will spend $26 million in efforts to produce about 1000 tons per year of lithium metal equivalent by 1984.

Lithium resources in the U.S. seem plentiful enough for the world's needs. At current production rates, Foote has 20 years' reserves in Nevada and 40 years' reserves in North Carolina. Lithium Corp. has 20 years' reserves in North Carolina.

Foote's president, E. Philip Comer, describes his company's reasons for developing in Chilean deposit as mainly defensive. "The Salar de Atacama is six times richer and 25 times larger than the Silver Peak deposit, which is the largest in the world to date," Comer says. "So we decided we could not ignore it, because it was very important to the lithium industry and to Foote in particular to participate in the development of this very rich deposit. It would be developed with or without Foote, and we felt it would be in our best interest to have it developed with Foote as a participant. We also felt that at the time this plant comes on stream in 1984, growth rates in lithium consumption would make it needed."

Lithium Corp. also has looked at production possibilities in South America. Company president Harold J. Andrews says the firm has exploration rights in the northern sector of the Salar de Atacama where Foote will not be producing, as well as in the Salar de Uyuni nearby in Bolivia. This activity is part of an overall development project by Gulf Resources & Chemical to produce such minerals as potash. Chilean law reserves lithium to the state, so Lithium Corp. would have to negotiate development rights. Andrews says his company is interested in developing lithium reserves in Bolivia or Chile because of possible lower production costs.

This intense, recent interest in lithium has been fueled by growth of applications in the glass, ceramics, and lubricant industries, as well as by heavy use in aluminum production, which began in the early 1970's. For the future, there is the prospect of uses in fusion reactors and in auto and utility load-leveling batteries.

About one third of all lithium cur-

Lithium chemicals at a glance

How produced—Isolation from spodumene ore and lithium-rich brines

Producers—Foote Mineral Co. and Lithium Corp. of America

Sales—7200 tons of lithium metal equivalent in 1980

Uses—Glass, ceramics, and lubricants 40%; aluminum production 33%

Foreign trade—Imports negligible, exports 33% of total sales

Prices—Lithium carbonate $1.45 per lb, lithium hydroxide $1.82 per lb

Value—$105 million for 1980 total sales

Lithium Corp.'s open pit mine near Cherryville, N.C. yields spodumene ore

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Lithium chemicals growing steadily in U.S., export markets

Tons of lithium metal equivalent	1980	1979	1978	1977	1976	1975	1974
U.S. sales	4750	4530	4310	4100	2800	2890	3770
Exports	2400	2100	2000	1800	1600	900	1000
Imports	160	10	10	10	10	90	70
Government sales[a]	0	0	5	253	164	61	430
U.S. production[b]	6990	6620	6295	5637	4226	3639	4270

a Surplus stocks of the General Services Administration, depleted of lithium-6. b Estimated by adding U.S. sales and exports and subtracting government sales and imports. Sources: C&EN, industry, and Bureau of Mines estimates

rently is consumed in the U.S. to make aluminum. Addition of 2.5 to 3.5% of lithium carbonate to electrolytic baths forms a eutectic mixture that allows lower bath temperatures, reduces power consumption, and minimizes volatilization of fluoride salts. Lithium is almost completely inert in aluminum potlines, and only 50 ppm of lithium winds up in the aluminum. This lithium level is satisfactory for most purposes, though it imparts an unwanted bluish tint to aluminum foil. Several companies have developed processes to remove lithium from aluminum for foil production.

In North America, 44% of all aluminum is produced using lithium, Comer says, in Europe 16 to 18%, and in Argentina, Brazil, and Venezuela 50%. Comer ascribes the relatively slow penetration of lithium use in aluminum production to reluctance on the part of many companies to make the initial high investment in lithium carbonate at $1.45 per lb. In the U.S., Reynolds Metals uses it in all of its production and Aluminum Co. of America in none, though Alcoa is trying lithium experimentally in one potline in Badin, N.C.

In ceramics, low-iron spodumene (lithium aluminum silicate) is used to make cooking ware with almost zero coefficient of thermal expansion to take extremes of temperature. In the glass industry, lithium carbonate increases productivity and prolongs glass furnace lifetimes. Lithium hydroxide goes into manufacture of lithium soaps, which are lubricant additives.

Though some lithium is used for batteries today, and though Comer predicts that lithium-based batteries will replace other dry cell types by 1990, the battery market will take relatively small amounts of lithium, he says. Andrews points out that eventual high-volume use of lithium in batteries depends on whether electric cars prove practical and metal sulfide-lithium batteries become the battery of choice for them.

If nuclear fusion reactors are ever developed, lithium-6 may be needed in very large amounts as a neutron absorber or to make tritium for fuel. Natural lithium contains 7.5% lithium-6 and 92.5% lithium-7. Indeed, the former Atomic Energy Commission spurred big lithium capacity increases in the 1950's when it bought large quantities to separate lithium-6 for hydrogen bomb production. But Andrews points out that there are processes to convert lithium-7 to lithium-6, which would reduce the amount of lithium needed for reactors. Too, beryllium and other materials could replace lithium-6 as a neutron absorber. Thus the amount of lithium needed for fusion reactors is open to question, and the question won't arise till the next century.

The General Services Administration still has about 80 million lb of AEC's surplus of lithium hydroxide, much of it depleted of lithium-6 and contaminated with mercury during the isotope separation process. At current use levels, this is sufficient for 65 years of lubricant additive production, which uses the hydroxide, or one to two years' world consumption of lithium in all forms. GSA is prohibited by law from selling in amounts and at prices that would disrupt U.S. production, however, and probably will sell no more than 1.2 million lb in any one year. The agency has not sold any since 1978.

Any chemist who ever took a qualitative analysis course would feel right at home in a lithium chemicals plant with its heavy dependence on solubility equilibria. At the spodumene mines of North Carolina, Foote and Lithium Corp. heat α-spodumene at 1100 °C in a kiln, which changes it to the β-form, increasing surface area by 30% and rendering the ore more susceptible to reaction with concentrated sulfuric acid at 250 °C. Water then dissolves lithium sulfate, separating it from insoluble aluminum silicate. Neutralization with soda ash precipitates most of the lithium as carbonate, yielding by-

product sodium sulfate, which both companies sell. Reaction of lithium carbonate with hydrated lime produces lithium hydroxide as well as calcium carbonate, which goes to a waste-disposal site.

Both lithium carbonate and hydroxide can be used to make salts by reaction with the appropriate acid. Electrolysis of molten lithium chloride with potassium chloride added to lower the melting point produces lithium metal. Lithium metal is used in metallurgical applications, batteries, and in production of organolithium polymerization catalysts. Lithium Corp. of Europe, subsidiary of Lithium Corp. of America, began production of organolithium compounds at Bromborough, near Liverpool, England, in 1980.

At the Nevada brine deposit, Foote Mineral adds soda ash to the brine to precipitate lithium carbonate. Lithium/magnesium ratios of brines are critical for successful separation of lithium, Comer says. There are about two dozen brine deposits in the region where northeastern Chile, southern Bolivia, and northwestern Argentina meet, but Salar de Atacama is the only one that is high in lithium, low in magnesium, and where high pumping rates can be achieved, Comer says. Brine wells must be pumped at 100 to 300 gal per minute to be economically feasible, Comer says, and Foote has test-pumped one well in the Salar de Atacama at 1000 gal per minute.

Foote will use solar evaporation to concentrate Chilean brine and crystallize out such unwanted compounds as sodium chloride. The company will truck the concentrated brine 20 miles south to a rail line for shipment to a chemical plant to be located in the Chilean coastal city of Antofagasta 120 miles away. □

Styrene to average 6% growth through 1985

Although worldwide demand for styrene will continue to grow nearly 6% per year on average through 1985, growth mostly will be outside the U.S. That's the gist of a new study called "World Styrene Analysis," by Chemical Market Associates, a Houston-based consulting firm.

By 1985, the study predicts, world styrene production will exceed 10.6 million metric tons a year, up from about 8.1 million metric tons in 1981. Production this year will be just 1.4% over 1980. Despite current recessions and generally poor demand for petrochemicals, the styrene growth rate will average 5.8% a year over the next five years, according to the study.

In the U.S., production in 1981, as it was in 1980, will come close to 3.1 million metric tons. U.S. exports are running ahead of expectations this year and will be the major reason that production can match 1980's output.

Unfortunately, the U.S. has a number of inefficient styrene units, which will require modification or shutdown for improved economics. Such inefficient units and higher crude oil prices in the U.S. will wipe out the cost advantage U.S. producers have enjoyed for several years.

As a result, the U.S. will begin to import significant volumes of styrene from Canada and the Middle East by 1985, the study says. By contrast, Far Eastern countries are likely to import less styrene from now on as new capacity in that area comes on stream. Western Europe, again for relative cost reasons, is expected to increase exports by 1985, as is South America.

In general, styrene plants eight to 10 years or older which have not been modified and updated face a 15 to 20% cost disadvantage, the study estimates. Producers unwilling to make changes in plants to improve production efficiencies will be forced out of the market. Even so, new worldwide construction, estimated to total 2.5 million metric tons of annual capacity, plus replacement capacity will keep plant operating rates below 80% of nameplate capacity during much of the next five years.

The use pattern for styrene worldwide will change slightly over the next five years, the study concludes. General-purpose polystyrene use will grow at about the same rate as styrene production, 5.8% annually, and the polymer will hold its leading position with a bit over half of all styrene uses. Expandable polystyrene use, not included in the general-purpose category, will grow at geographically varying rates. But consumption rates in developed countries could be large, such as 9% annually in the U.S. The share of styrene consumed by styrene-butadiene rubber will drop slowly, with a worldwide growth rate averaging 3.8% annually to 1985. □

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Fischer-Tropsch: new life for old technology

Helping to revive this venerable process is surge of research activity, mainly on mechanisms, catalysts, and reactor design

Joseph Haggin
C&EN, Chicago

Fischer-Tropsch synthesis may be ripe for revival. But it won't look much like the original. A flurry of R&D activity focused on mechanisms, catalysts, and reactor design is putting new flesh onto the venerable but historically dead-ended technology.

Historically, the technology for converting the hydrogen/carbon monoxide synthesis gas from coal was used to produce motor fuels. However, with its new vigor, the technology is being directed toward production of basic hydrocarbons.

What could help bring about this Fischer-Tropsch (F-T) revival is a shift in the raw material base for chemicals from oil and gas to coal, which already has begun. The shift likely will be gradual, perhaps halting from time to time, and may reflect the economics of oil and gas substitution. A key item in the shift to coal will be the development of coal conversion technology.

Some chemicals are obtained directly from coal via traditional coal tar chemistry. Others are expected to be obtained from various types of direct liquefaction now under development. Most of the major commercial chemicals, however, probably will come from synthesis gas chemistry, and in the beginning the most likely processes are those that already have been demonstrated to be commercially operable. An obvious choice is F-T synthesis.

The F-T synthesis originated in Germany in the 1920's, reached its zenith in Germany during World War II where it provided primarily motor fuels, and survives now only at the Sasol works in South Africa (C&EN, Sept. 17, 1979, page 13). Immediately after World War II, most industrial nations had F-T-based projects in progress and these were kept going briefly until cheap oil and gas made chemicals and fuels from coal noncompetitive.

By 1960 the world supply of natural gas began to decline, and cheap oil began to be imported from the Middle East. Naphthas and reformed natural gas became the principal sources of feedstocks. Large amounts of propylene, butadiene, and aromatics were coproduced. This development proceeded well into the 1970's despite the Arab oil embargo of 1973 and the subsequent rise in crude oil prices.

However, industry's reaction following the 1973 embargo was to seek a new economic equilibrium and this, in essence, was manifested in finding a competitive source for oil and gas. In principle any carbonaceous source can be used, but attention has been centered almost entirely on coal. The reaction of the technical community was to revive those coal conversion projects that had been all but abandoned by 1960.

In the case of F-T syntheses, this activity yielded a three-pronged program to convert F-T technology to chemical feedstock production rather than to confine it strictly to motor fuels. One program is aimed at development of more selective catalysts to improve the yield of C_2 to C_4 olefins. A second program is aimed at the production of a coal-derived naphtha suitable as a cracker feedstock. The third program is aimed at producing C_{10} to C_{20} aliphatic, straight-chain hydrocarbons for making detergents.

At the beginning of the program most of the available technical data came from the experience of the Sasol plant and it was not encouraging. For example, the original aim was to raise the total olefins production to 50% of the product slate. This required a sharp improvement in catalyst selectivity. Experience had shown that selectivity could be varied slightly by changing process operating conditions, but the 50% olefins goal seemed out of the question without some radically new catalysts.

At present, catalyst and process improvements have permitted total olefin production up to 90% in pilot runs. And in at least one laboratory

Sasol in South Africa is only commercial plant using Fischer-Tropsch process

experiment a 100% yield of a single olefin, namely propylene, has been achieved.

The wide-ranging catalyst improvement programs also have sharply improved the motor fuel potential of the F-T synthesis. The net effect is that whereas the utility of F-T technology has been considerably broadened from motor fuels to include commercial petrochemicals, F-T technology has been made a very general method of commercial synthesis that is being adapted to many local requirements.

The case for F-T technology has been summarized in a multiclient study made by Catalytica Associates, a San Francisco research and consulting firm specializing in catalysis. The main factors motivating current industrial catalysis research are rising energy and feedstock costs, decreased petroleum reserves, environmental constraints, and sharply increased investment costs. The use of coal-derived synthesis gas overcomes most of these problems. More than 65% of the world's recoverable fossil fuel reserves are coal; oil accounts for only 10%. The U.S. has more than abundant coal reserves.

Furthermore, Catalytica's president, James A. Cusumano, believes that chemicals and fuels from coal are likely to become competitive with petroleum-based products because the price of oil is expected to rise faster than the price for coal. Cusumano believes that a coal-based synfuels industry likely will appear in the next decade. That implies a large gasification industry, which is the requisite source of syngas for F-T technology and other C_1-based processes.

Another assessment of C_1 technology in general and F-T technology in particular has been made by A. Eugene Cover, manager of the synfuels process division of M. W. Kellogg Co. Cover notes a number of projects are moving ahead without government participation. The general development activity is very high and, he predicts, will result in commercial production in the next few years. According to Cover, there are 10 major coal gasification processes, six major liquefaction processes, and five in-situ shale oil processes along with nine more processes for aboveground use now in various stages of development. Of the gasification processes, seven are now commercial. Two of the coal liquefaction processes are commercial. None of the shale oil processes are yet commercial.

Cover notes that it is important to

Fischer-Tropsch reaction: the chemistry

The chemistry of the Fischer-Tropsch synthesis usually is defined by consensus, with many individual reservations depending on viewpoint. The classical F-T synthesis has been described by Robert B. Anderson, formerly supervisory chemist at the Bureau of Mines, as a hydrogenation of carbon monoxide producing higher hydrocarbons and oxygenated organic molecules that have predominantly straight carbon chains, at least in the range C_4 to C_7. This was considered distinct from higher alcohol synthesis and iso-synthesis. The F-T synthesis is a composite of many reactions, producing a variety of product molecules of different types. The mechanism is not well defined, is extremely complex, and provides at various times and in various environments low- and high-molecular-weight liquids and gases, carbides, oxides, carbonyls, and elemental carbon.

A more modern view is that of Jurgen Falbe, executive vice president of West Germany's Ruhrchemie A.G. This view claims that all the reactions in the F-T synthesis can be reduced to two. The first is the actual F-T conversion:

$$CO + 2H_2 \rightarrow (-CH_2-) + H_2O \qquad (\Delta H_R = -39.4 \text{ kcal})$$

The second is the water-gas shift reaction, which proceeds easily as a consecutive reaction on iron catalysts:

$$CO + H_2O \rightarrow H_2 + CO_2 \qquad (\Delta H_R = -9.5 \text{ kcal})$$

The net overall reaction can be summed as:

$$2CO + H_2 \rightarrow (-CH_2-) + CO_2 \qquad (\Delta H_R = -48.9 \text{ kcal})$$

If olefins are formed exclusively in a totally stoichiometric conversion, the maximum yield is 208.5 g per cubic meter of synthesis gas. The shift reaction can be suppressed by operating the system at low temperatures, short residence times, and by recycling dry synthesis gas.

Undesirable side reactions include methanation, decomposition of carbon monoxide, and oxidation of the catalyst. Optimal product yields can be obtained only when reactants are provided with a CO/H ratio that is the same as that at which the reactants actually are consumed. Any difference between the two values decreases the yield of the desired products.

A more inclusive definition of F-T synthesis, although substantially the same, has been included in a recent study by Oak Ridge National Laboratory. The study limits F-T chemistry at present to the following basic reactions:

$$(2n + 1)H_2 + nCO \rightarrow C_nH_{2n+2} + nH_2O$$

$$(n + 1)H_2 + 2nCO \rightarrow C_nH_{2n+2} + nCO_2$$

$$2nH_2 + nCO \rightarrow C_nH_{2n} + nH_2O$$

$$nH_2 + 2nCO \rightarrow C_nH_{2n} + nCO_2$$

$$2nH_2 + nCO \rightarrow C_nH_{2n+1}OH + (n - 1)H_2O$$

$$(n + 1)H_2 + (2n - 1)CO \rightarrow C_nH_{2n+1}OH + (n - 1)CO_2$$

Again the water-gas shift reaction is included as a means of adjusting the CO/H ratio in the synthesis gas. Competing reactions, most notably the formation of methane, are suppressed by any means available because they inhibit the formation of longer chain hydrocarbons.

Another modification included by Herbert Kölbel of the Chemical Engineering Institute at the Technical University of Berlin is the Kölbel-Engelhardt (K-E) synthesis, which forms hydrocarbons from carbon monoxide and water (steam). Kölbel suggests that this be written as:

$$3CO + H_2O \rightarrow (-CH_2-) + 2CO_2 \qquad (\Delta H_R = -244.2 \text{ kJ})$$

Other competing reactions that can complicate the synthesis include the Boudouard reaction:

$$2CO \rightarrow C + CO_2$$

coke deposition:

$$H_2 + CO \rightarrow C + H_2O$$

and carbide formation:

$$xM + C \rightarrow M_xC$$

Typical carbides are Fe_2C, Co_2C, and Ni_3C. All rather drastically alter the catalytic behavior of the metal species. Nickel catalysts are not usually the catalysts of choice, and both iron and cobalt are considered the "classical" F-T catalysts. Cobalt was first employed by Fischer and Tropsch and from mechanistic considerations was considered primarily an olefin former. For economic reasons iron catalysts replaced cobalt in most applications of F-T technology, particularly in World War II. Like cobalt, the iron catalysts are often regarded as olefin formers. The acceptance of hydrogenation offered no problems before 1973, when the emphasis in F-T research shifted to olefins production. Kölbel claims that in modern processes, olefin content can vary from 0 to 90% with appropriate process management and that about 80% of the olefins formed are *n*-alpha-olefins.

Fischer-Tropsch reaction: the mechanism

At least 14 mechanisms are known to be published explaining the Fischer-Tropsch synthesis. Most investigators accept the impossibility of stating a definitive mechanism at this time.

The main problem, according to Jurgen Falbe, executive vice president of West Germany's Ruhrchemie A.G., is that many of the investigations on which various mechanisms are based were made on model systems, which are far removed from commercial reality. The most widely discussed mechanism, Falbe claims, is carbon chain growth at the chain terminal. Excited molecules result from simultaneous chemisorption of carbon monoxide and hydrogen at the catalyst surface. There they react to form a primary enolic complex. Chain growth begins with the splitting off of water from two complexes and leads to the formation of a C-C bond and the simultaneous release of a carbon atom from the catalyst surface by hydrogenation. The C_2-complex splits off water and is released from the metal by hydrogenation. Through condensation and hydrogenation there is stepwise growth, one carbon atom at a time. Eventually the complex desorbs, carrying with it a hydroxyl group, which can, in subsequent reactions produce aldehydes, acids, alcohols, esters, etc.

The hydrocarbons can be formed either from the alcohols by dehydrogenation or by cleavage of the adsorption complex. Chain growth also can start with alcohols and/or aldehydes when these are adsorbed on the catalyst surface in the enol form. Chain growth also can begin with olefins, which Falbe believes are probably bound to the catalyst surface in enolic form after reaction with water.

The above mechanism is the most likely, if not the only possibility, to a consensus of F-T investigators. There is much evidence supporting it. The formation of a primary enolic complex is considered supported by the fact that, under otherwise equal conditions, the amount of gas mixture adsorbed is larger than the sum of the individual adsorption components. Similarly, the heat of adsorption for the mixture exceeds the sum of the adsorption heats of the individual components and corresponds to the calculated enthalpy of formation of the primary enolic complex. Formaldehyde has been shown to be the first reaction product by mass spectrometry, and quantum calculations indicate that formation of the primary enolic complex is energetically favored.

The most recently suggested F-T mechanism has been proposed by Richard S. Sapienza of the catalysis group at Brookhaven National Laboratory. He outlined the mechanism in August at the New York meeting of the American Chemical Society. Sapienza claims that the oxide mechanism encompasses the observations of earlier theorists and, more to the point, is useful in predicting catalyst behavior. The fact that Sapienza's group has, apparently, been successful in developing some new, highly active F-T catalysts, lends credence to the claim.

Fundamental to understanding the oxide mechanism is the idea that carbon monoxide chemisorbs on a metal surface and reacts with hydrogen to yield an oxygen rather than a carbon coordinated species. The consequences of this mechanism are considerable. Bond strengths of metal oxides should correspond directly to specific activity of methanation, but should be related inversely to methane selectivity. Oxidation of the catalyst surface should increase both catalytic activity and selectivity. Metals that form nonreducible oxides should react with carbon monoxide and hydrogen, yielding methane and leaving behind a surface oxide coating. This reaction has been observed. Previously attempted catalytic reduction of carbon monoxide suggested that the formation of metal-oxygen bonds may be necessary for synthesis to occur. The very strong bonds of metallic oxides investigated at Brookhaven may explain why these reductions could not be made catalytic.

The metal-oxide bond strength also will determine the probable product distribution. Weak oxide formers, such as rhodium, should produce ethylene glycol, whereas a strong oxide former, such as iron or manganese, should yield ethylene. Mixed systems should give good yields of ethanol. The same logic applies, says Sapienza, to the effects of promoters. The addition of a weak oxide former should decrease methane and olefin formation and vice versa.

The oxide mechanism is still under scrutiny. One of the concerns voiced by critics of the oxide mechanism is that it involves structures that are unusual and even unprecedented in the literature. Examples are those involving tetravalent oxygen coordinated to the metal. It also is difficult for traditionalists to accept the production of such species as $M{-}O{=}C$, $M{=}O{=}CH_2$, $M{-}O{=}CH_2$, and $M{-}O{-}CH_3$. Sapienza is well aware of the criticisms and is refining the mechanism to meet objections.

remember that in the area of coal liquefaction only two processes are now available that can be considered truly commercial. Coal liquefaction is a category that includes all coal products other than methane or fuel gases. Those processes are the ICI/Lurgi/Topsoe methanol process, and the Kellogg/Sasol version of the Fischer-Tropsch process. This is the major reason why so much interest is being centered on F-T processing.

In fact, the F-T process is the only extant commercial indirect liquefaction process available. That is not to say that it will remain so, but it at least suggests that F-T processing will become the mainstay of efforts involving C_1 chemistry from synthesis gas in the near future. Cover thinks that this is particularly true because the F-T process is the only commercially available process for products other than motor fuels—specifically low-molecular weight olefins.

F-T catalysts traditionally have been producers of a broad spectrum of molecular weights. The new specificity exhibited by catalysts in recent years, and the efficacy of some of the newer processing techniques—such as improved slurry reactors and flame-spraying of catalysts on tube surfaces—indicate that F-T processing can be tailored to specific needs and can be made considerably more flexible than in former years.

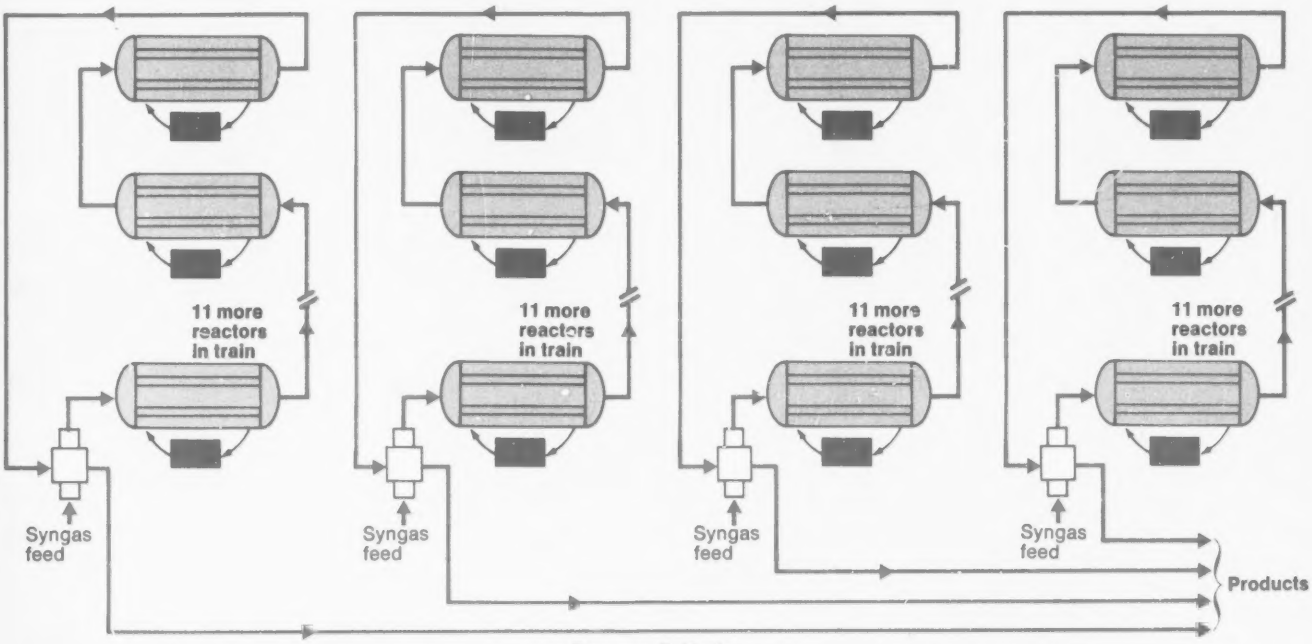
One tabulation reports at least 5000 publications and 5000 patents relating to F-T catalysts. Since 1926, says one F-T chemical expert, "just about everything but Rasputin's beard has been tried as a catalyst."

Chemists at West Germany's Ruhrchemie A. G. generalize that the 3d and 4f transition metals and their insertion compounds (carbides, nitrides, etc.) are especially suited for the adsorption of the primary F-T complex. However, from a practical viewpoint, only iron and cobalt are useful commercially. Nickel is all but useless because it favors methanation of the synthesis gas. Platinum group metals show little activity. Rhodium produces oxygenates and osmium favors formation of gaseous products. Ruthenium catalysts seem to favor high molecular weights, and compounds with molecular weights of more than 200,000 have been made. Titanium, vanadium, chromium, and manganese are not effective because of the difficulty in reducing their oxides. Molybdenum is currently under investigation but the results are as yet unknown.

The reactants produce some profound changes in the fresh catalysts

Four of leading Fischer-Tropsch processes possibly suitable for use in U.S. were

Tubewall reactor system, flame-sprayed catalyst



Four parallel trains

= Dowtherm loop generating steam

Operating parameters:
Outlet temperature = 338 °C
H_2/CO feed ratio = 2.0
No recycle

Basic design by Ralph M. Parsons Co. from development of PETC

Fischer-Tropsch reaction: the thermodynamics and kinetics

A survey of five reviews of F-T technology reveals virtually no thermodynamic information on F-T technology as a composite subject. There is only minimal information on this aspect. The reason for this lack lies in the complexity of F-T chemistry. Thermodynamic calculations of the formation probabilities in an F-T reaction are impossible because there are, theoretically, an infinite number of reaction equations.

A review by Ruhrchemie A.G. notes that, in practice, F-T thermodynamics is based on the assumption that individual reactions are independent. There is no synthesis gas composition that corresponds to a stoichiometric starting point for all reactions simultaneously. The inference is that product concentrations will depend strongly on the composition of the feed gas. About the only generalization made in the Ruhrchemie review is that hydrogen-rich feeds favor paraffin formation, and carbon monoxide-rich feeds favor olefin and aldehyde formation.

All of the reactions encountered in the F-T synthesis are exothermic, some of them highly exothermic. Excepting methanation, all the F-T reactions are thermodynamically not favored above 450 °C. The higher the temperature, the greater the tendency to form methane. Hydrogenation of carbon dioxide is more likely than hydrogenation of carbon monoxide. Paraffins are only slightly more likely in a F-T synthesis than are olefins. The conclusion that seems inescapable is that F-T chemistry, at least of the classical variety, is rather more empirical than researchers might like to admit.

The kinetics of F-T chemistry are only slightly better known than the thermodynamics. A generally valid kinetic equation for F-T chemistry cannot be written. Each type of catalyst and each individual process variation contribute to a unique variety of kinetics that, in general, cannot be extrapolated or interpolated.

Although mass transfer plays an obvious role in F-T kinetics, the role appears to be restricted to pore diffusion to a rather shallow depth. Mass transfer through adhering hydrocarbon films is claimed not to be a rate-determining feature.

The conclusion is that little is known about gross kinetics (macrokinetics), although there is a considerable body of knowledge concerning the kinetics of individual F-T reactions. A problem is that the data on individual reactions are all but impossible to correlate because of the wide differences in the practices of the individual experimenters.

The Oak Ridge study notes that since 1951, three major attempts have been made to organize F-T kinetics. The results have not been encouraging. Despite great numerical differences in the data—usually attributed to differences in catalyst samples—the consensus is that F-T reactions are about first order in hydrogen partial pressure and zero order in carbon monoxide as long as the H/CO ratio is between 1 and 3. The kinetic data on methanation, by contrast, is large in amount, rather more consistent, and reliable.

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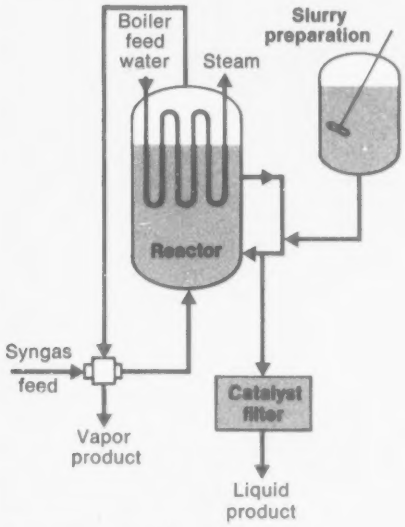
focus of UOP evaluation

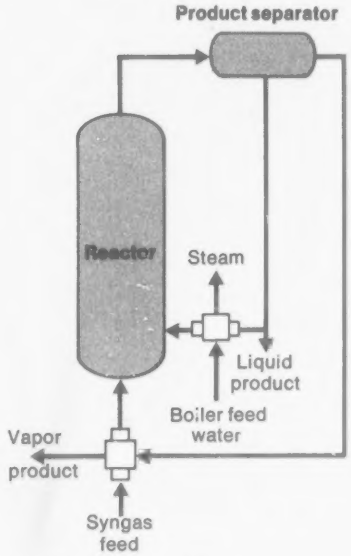
Slurry reactor system



Operating parameters:
Outlet temperature = 275 °C
H_2/CO feed ratio = 0.7
No recycle

Basic design by Herbert Kölbel, current development by Rheinpreussen-Koppers

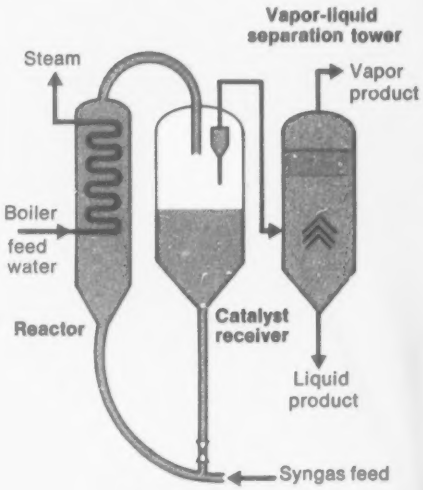
Ebullating-bed reactor system



Operating parameters:
Outlet temperature = 286 °C
H_2/CO feed ratio = 0.7
No recycle

Basic design by Bureau of Mines, recent development by Chem Systems Inc.

Entrained-bed reactor system



Two systems are required in parallel

Operating parameters:
Outlet temperature = 335 °C
H_2/CO feed ratio = 2.4
Recycle ratio = 2.3

Basic design by M. W. Kellogg Co.

of the iron group that result in the active catalyst phase. The phase diagram for cobalt is not very complicated but that for iron is very complex. This is attributed to iron's ability to form inclusion compounds with nitrogen, boron, carbon, etc. It is known for certain that iron catalysts undergo significant phase changes during reaction.

Two types of promoters generally are used in the classical F-T synthesis. Metal oxides are structural promoters that form large surface areas and inhibit recrystallization of the active catalyst. Alumina, thoria, and magnesia are examples of this class.

The other class, energetic promoters, as their name indicates, achieve their effects via molecular electronics. Chemically active structures also can function as electronic promoters. The alkali metals, for example, appear to produce promotion of F-T reactions in both ways simultaneously. Alkali carbonates are particularly good electronic promoters for iron catalysts. The general effect of promoters appears to be, simultaneously, the increased chemisorption of the reactants, easier primary complex formation, and improvement of the rates of all carbon monoxide consuming reactions.

The biggest problem facing F-T catalyst developers is the complete change in emphasis from motor fuels to low-molecular-weight olefins as the primary products The prospect of another 25 years of laborious, somewhat empirical catalyst development is not very enticing. One bright light in the tunnel may be a technique being developed by Richard S. Sapienza of the catalysis group at Brookhaven National Laboratory.

Sapienza and his associates had as a goal the development of new, highly active catalyst systems for F-T chemistry. The ultimate purpose was to produce diesel fuel and jet fuel from synthesis gas. Cobalt was the catalyst of choice because it was the most active nonnoble metal available. However, cobalt must be promoted to assist the cobalt oxide reduction. The materials chosen were platinum and palladium, both presenting problems in catalyst formulation.

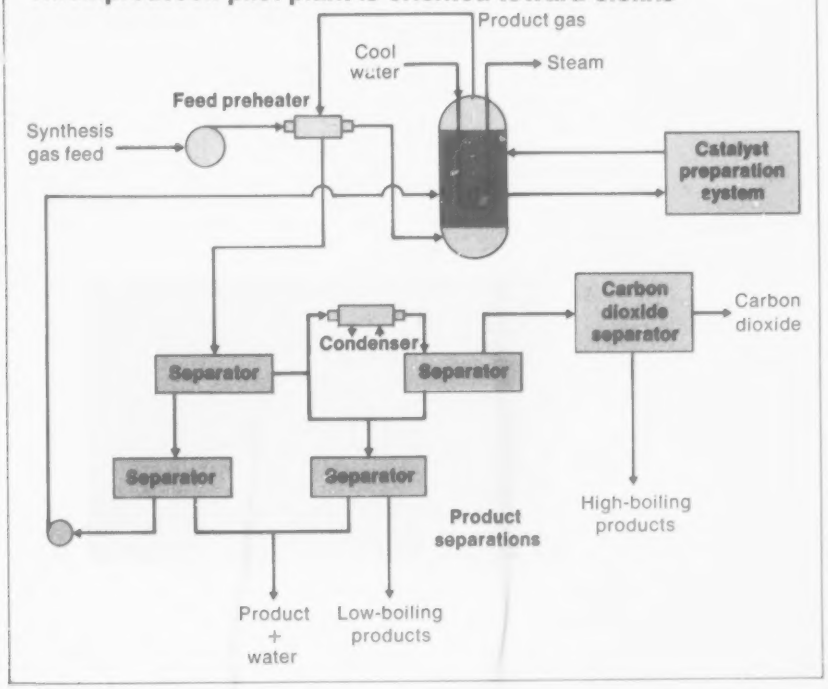
Eventually it was discovered that cobalt carbonyl reacts under certain conditions to deposit metallic cobalt on some supports, such as alumina. This runs counter to previous belief, but the resulting Co/Al_2O_3 catalyst displays good F-T activity.

This sort of technique led to a series of highly active F-T catalysts that proved useful in bench trials for motor fuel production. Reflecting the initials of Sapienza and his associates, the catalysts are referred to as SOSS catalysts.

To illustrate the improvements that are represented in the new catalyst system, Sapienza cited one SOSS catalyst that has the superficial composition $120Co/5Pt/100Al_2O_3$. At a temperature of 225 °C the catalyst exhibited an activity of 3000 g of product per kg of metal per hour. At the same temperature, a commercial catalyst with the superficial composition $2K_2CO_3/9Al_2O_3/30SiO_2$ had a corresponding activity of 24. This is an extreme case but most of the SOSS catalysts reported by Sapienza's group are one or two orders of magnitude more active than are presently used catalysts. The products reported for the SOSS catalysts are total hydrocarbons.

Most of the experiments with the

Rheinpreussen pilot plant is oriented toward olefins



SOSS catalysts have been conducted in a batch slurry reactor. Normally catalysts are prepared in situ under synthesis gas pressure from $Co_2(CO)_8$ and either supported platinum or palladium components. The usual solvents are cyclohexane, xylene, and tetrahydrofuran. Hydrogen gas alone also can be used for catalyst preparation, which leads to a new heterogeneous catalyst in the slurried state. The type of solvent plays only a minor role in catalyst performance.

SOSS catalysts have been used in the temperature range of 150 to 250 °C, with the exception of one particular sample that was used at 70 °C with good results. Catalyst concentrations of up to 7% by weight in the solvent have been used. Pressures ranged from 500 to 1500 psig, but even lower pressures may be used. The consumption ratio of hydrogen to carbon monoxide has always been near 2:1.

Sapienza says that the preferred way to use the SOSS catalysts is in a slurry. The catalysts are heterogeneous, and all the evidence gathered so far suggests that they remain so in use. The catalysts also are magnetic, which is helpful in recovery and reprocessing. So far, all of the experimentation has been in batch. The next step is a small continuous pilot plant that will permit evaluation systems that more closely resemble actual industrial environments.

Another possible new development is associated with work on the fast fluid bed coal gasification process under development by Hydrocarbon Research Inc. According to HRI's Derk T. A. Huibers, manager of new process development, some thought is being given to the possibility of incorporating F-T catalysts of a special type in a gasifier. The inference is that F-T synthesis and synthesis gas production might be achieved in the same unit. Considering the high temperatures in the gasifier, reaching this goal remains a challenge indeed.

Among the newer types of F-T catalysts suggested by Mobil Research & Development is the incorporation of an excess volume of ZSM-5 zeolite with the iron catalysts. The selectivity for gasoline thus can be increased to more than 60% of the total hydrocarbon product and, essentially, 100% of the liquids produced. The mechanism has not been determined, but it appears that the zeolite function is to intercept molecular intermediates in the propagation sequence and convert them to forms that are inert to further chain growth.

Ultimately the success or failure of F-T technology will be found in the operating system. A study by Oak Ridge National Laboratory notes that seven major types of reactors have been used to date. The original reactor had a fixed bed of pellets that operated at temperatures from 200 to 270 °C and produced liquids that were about half gasoline and half heavier hydrocarbons. Precise temperature control was difficult, and hot spots inevitably developed, which led to catalyst deactivation and carbonization.

Fluid-bed reactors first were used with fluidized mill scale for catalysts. These operated at higher temperatures (300 to 330 °C), made a lot of methane, and had low selectivity. The Bureau of Mines developed a reactor that used granules of fused iron or steel lathe turnings circulated through the bed with an oil carrier. Temperature was in the range of 235 to 280 °C, with heat removal via circulated oil and an external heat exchanger. This reactor had a low conversion rate and the catalyst disintegrated with time.

A modified fixed-bed reactor also has been designed to recycle hot tail gases over the catalyst pellets for temperature control. This operated at up to 340 °C, and the products were lighter than before. The cost of hot gas recycle was prohibitive.

The slurry process uses a precipitated or fused catalyst suspended in a heavy oil. Synthesis gas bubbles pass through the suspension at less than 300 °C. Liquid products are filtered out, and the catalyst is reusable. Liquids may be as much as 80% gasoline, and very little methane is produced.

The Arge reactor is an improved fixed-bed unit, with very heavy catalyst loadings and higher space velocity. About 40% of the liquids formed are gasolines; most of the rest are heavier.

Entrained-bed Synthol reactors developed by M. W. Kellogg Co. are probably the most popular commercial reactors at present. A fused magnetite catalyst and reactants are mixed at the bottom of the reactor. These travel up through the reaction zone at 300 to 335 °C, where heat is removed by two boilers. Products and catalysts are separated by cyclones and settlers. About 78% of the liquids are naphthas, 7% are heavier oils, and the rest are alcohols, acids, etc.

With the Sasol plant being the only commercially operating F-T plant, a first approach to adapting the technology to other places would be duplication of the Sasol installations. Studies of this alternative quickly indicate that duplication of Sasol's plant is economically unsuitable almost everywhere else in the world.

The present trend appears to be to

develop a more modern installation based on a new F-T plant complex. For this purpose, some new reactors or some old reactors in new configuration have been evaluated by UOP Inc. under contract to the Department of Energy.

The UOP study evaluated four of the leading F-T systems that might be suitable for use in the U.S. In each case the object was to maximize gasoline production, although it was recognized that the shift in emphasis toward low-molecular-weight olefins was taking place. The four systems included the M. W. Kellogg's Synthol system, the tubewall reactor with a flame-sprayed catalyst, the slurry reactor, and the ebullating bed.

The tubewall reactor is essentially a heat exchanger. An active iron catalyst is deposited on one side of the tube. The original work on the tubewall reactor was done at the Pittsburgh Energy Technology Center. It subsequently was used in a conceptual design by Ralph M. Parsons Co. for DOE. The catalyst used in the Parsons design was potassium-promoted taconite.

The slurry reactor has been under development in Europe for many years, and is now considered ready for commercial production. The basic idea is to suspend the catalyst particles in a high-temperature liquid, usually slack wax, and then bubble the synthesis gas through the reactor. In effect, it is a three-phase fluidized bed, but the small catalyst particle size eliminates the effect of a solid phase and the slurry functions as a bubbling liquid.

The ebullating bed is much like the slurry reactor in that the catalyst particles are suspended in a liquid, and gas is bubbled through the bed. The main difference is that the particles are much larger, and the system is a true three-phase system. This work has been revived recently by Chem Systems Inc.

The UOP study aimed at using a reaction engineering approach to identify the inherent strengths and weaknesses of each system. A common basis for evaluation was adopted, including the specification of a plant size, product slate, and reaction mechanism. The mechanism selected was assumed to include a polymerization process, was consistent with the generation of normal paraffins and olefins as final products, reflected the nonselective distribution of the traditional F-T process, and incorporated an equilibrium between the olefins on the catalyst sites and olefins in the surrounding gas phase.

Primary products in the UOP model are derived from two basic reactions. One is the hydrogenation of alkyl chains of random length to form paraffins. There also is an adsorption-desorption series to form olefins. In both cases, the termination step for an active intermediate regenerates a catalyst site, which can again participate in chain growth. This means that there is a constant number of active sites.

Inherent in F-T chemistry is the water-gas shift reaction. The UOP study assumed that the shift reaction would not compete for active sites and was not assumed to be proportional to the available F-T sites.

The basis for design was a plant that converted about 28 million standard cu ft per hour of synthesis gas. This corresponds to a refinery equivalent of 25,000 barrels per day and is typical for indirect liquefaction plants.

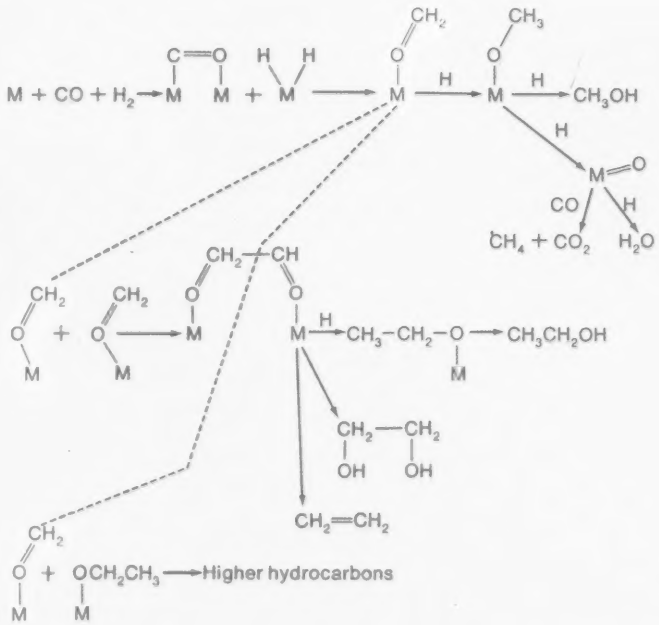
Similarly, the operating pressure for the reactors was set at 400 psi, which is considered typical for a modern gasifier. The entrained bed is the only reactor evaluated that used recycle in its operation. Although the basic operational features of all four designs were maintained, UOP made some changes for consistency in evaluation.

One point of evaluation was the investment costs for the four systems. Another point of comparison was annual catalyst cost. The ebullating bed had the highest catalyst cost at about $14.4 million per year. The tubewall reactor was about the same. Lowest catalyst cost was exhibited by the slurry reactor at $760,000 per year. The entrained bed had costs of about $6.72 million per year.

Thermal efficiency of the process also was considered. The heat of reaction in an F-T system is about 25% of the heat of combustion of the synthesis gas fed to the system. For economic reasons it is necessary to recover as much of this heat as possible. The total thermal efficiency of the entrained-bed system was estimated to be about 66%, the tubewall reactor system 85%, and the two slurry systems about 91%. The inherently higher efficiency of the slurry and ebullating-bed systems is attributed to more efficient use of the water-gas shift reaction.

The total product yield for all four types of reactors is about the same, but the molecular weight distributions are quite different. On the basis of maximum gasoline yield, the slurry and ebullating-bed reactors have a clear edge. However, it has been observed that all four systems are operated at the conditions of the study and that is self-limiting. It is probably true that any of the four systems could be operated at a more desirable product slate, but the comparisons still are considered generally valid.

Brookhaven group proposes oxide mechanism



Slurry is least costly F-T system

Components	Index of investment costs[a] Entrained bed	Tube-wall	Slurry	Ebullating bed
(Number of reactors)	(2)	(52)	(18)	(20)
Reactors and receivers	34	189	33	28
Other vessels	30	—	~1	—
Heat exchangers	32	15	10	21
Pumps	4	4	2	16
TOTAL	100	208	46	65

a Based on total for entrained bed = 100. Source: UOP Inc.

The UOP study clearly shows that the most important product variable in all systems is the temperature, followed closely by the hydrogen-carbon monoxide ratio. By all counts, the slurry reactor has the clear advantage under the terms specified by the study. Further investigation suggests that the slurry reactor also may be the reactor of choice for low-molecular-weight olefins.

Designing plants for the production of a single specific product is inherently more risky than for one that is flexible and that can be used for a variety of products. This is one of the problems being faced with the F-T plants now being considered for olefins production. Herbert Kölbel of the chemical engineering institute at the Technical University of Berlin claims that the slurry process does not suffer from this limitation. The slurry process, he says, is inherently flexible, a major asset when the cost of the synthesis gas represents about 80% of the operating costs.

The variable selectivity of the slurry reactor is achieved by a combination of catalyst selection and the set of operating parameters. Kölbel illustrates flexibility by citing two examples. In the first, a low-molecular-weight olefin-rich product was made containing in excess of 87% hydrocarbons boiling under 200 °C with an olefin content of 80%. The catalyst is a regenerated iron precipitation catalyst with 0.1% potassium carbonate added as a promoter. The operating temperature was 278 °C. An alternative method of producing low-boiling olefins is by recycling a portion of a higher boiling fraction over suitable iron catalysts.

An intriguing property of the slurry reactor is the ability to program temperature along its length. This permits higher capacity afforded by higher temperatures without the corresponding production of methane. Methane formation is inhibited by lower synthesis gas concentrations as well as low temperatures. To take advantage of these facts, the temperature in the reactor is allowed to rise from 30 to 60 °C with height.

High-molecular-weight products are favored by lower operating temperatures, typically 225 °C, and by the proper choice of catalysts. It also can be favored by the accumulation of chain-extending molecules through the removal of recycle filtrate. Oxygenate production can be favored by adding potassium carbonate to the slurry. One experiment yielded about 60% alcohols, mostly C_2 to C_5, in the product.

According to Kölbel, the flexibility of the slurry process can be extended to the Kölbel-Engelhardt synthesis by replacement of the hydrogen by steam. Suitable catalysts are iron, nickel, cobalt, and ruthenium. This process is claimed to be particularly suited for the use of carbon monoxide-rich waste gases. Optimum temperatures lie between 250 and 300 °C with the pressure adjusted such that the carbon monoxide content of the synthesis gas is about 35%. At 20 atm, experiments show that conversion of 90% of the carbon monoxide is possible in a single pass. Most of the products are in the C_2 to C_{10} range, and the olefin content is high because of the absence of hydrogen in the feed.

New catalysts are under development for F-T systems in general, but there is particular interest in their development for slurry systems. A West German program of catalyst development has been in full gallop since 1974. One group of catalysts consists of iron modified by additions of titania, vanadia, molybdenum oxide, and oxides of manganese and cobalt. A second group consists of catalysts whose selectivity is achieved by partially poisoning the surface with sulfur. This is supposed to shift product distributions toward the low molecular weights. One specific example is the discovery that iron whiskers exhibit very high selectivity when partially poisoned and when given promoters of potassium, gold, and cobalt.

A third group of catalysts is under development at Sasol and is proprietary. A final group consists mostly of manganese catalysts developed by Kölbel and his associates in Berlin. The high performance of these catalysts is attributed to the variability in iron-manganese ratio over a wide range. High iron content leads to more saturated products and vice versa. Selectivity of these catalysts is claimed to be four or five times those of previously employed materials.

The prospect of very large slurry reactors in the near future has prompted a flurry of design studies, and one of the major problems that has emerged is ensuring the stability of very large masses of slurry medium. According to Kölbel, the target for designers of slurry systems is a large-diameter reactor with heights of up to 26 ft. The internal hydraulics are complicated by the minute bubble behavior. Another problem is minimizing the tendency for the slurry to "donut" in flow pattern. All these problems are those normally associated with bubble trays in distillation columns and there is every expectation to believe they will be solved in due course.

Numerous attempts at piloting the slurry process have been made since 1944. The oldest example, and the one which still is at work is the pilot plant for the Rheinpreussen-Koppers process, operated at Rheinpreussen A.G. in West Germany. After World War II, the pilot was scaled up 300-fold, reportedly without difficulties. The original purpose was to make gasoline, and this was successful. Gasoline with an octane number of 83 was achieved with one pass through the reactor and a total carbon monoxide conversion of 91%.

The plant was subsequently used to produce a more olefins-oriented product slate, and this program is still in progress. One of the operational changes in the new program is use of multistage operation, which increases throughput and efficiency simultaneously. This increase is attributed to underestimation of the original pilot reactor capacity.

The current belief that F-T synthesis is about to undergo a commercial revival is based on high probability that a large coal gasification industry is still rather close to being instituted and that the gasification industry will constitute the base for provision of synthesis gas. F-T technology already has undergone some rather great changes in character since 1973 and probably will undergo even greater changes in the near future. The acceleration of catalyst development is, apparently, solving much of the problem of traditional F-T synthesis: poor selectivity. The slurry reactor and other new fluidized processing media are improving production rates at minimum costs. The only real impediment, and in the long term the one that really matters, is the economics of oil-based production of fuels and chemicals. □